Upper Skagit Indian Tribe
Bow Hill Road Reservation

WASTEWATER TREATMENT FACILITY PRE-DESIGN REPORT

WILSON ENGINEERING, LLC

Consulting Engineers
805 Dupont Street, Suite #7
Bellingham, Washington 98225

December 3, 2008

Project # 2007-101

Wilson
SURVEY/ENGINEERING

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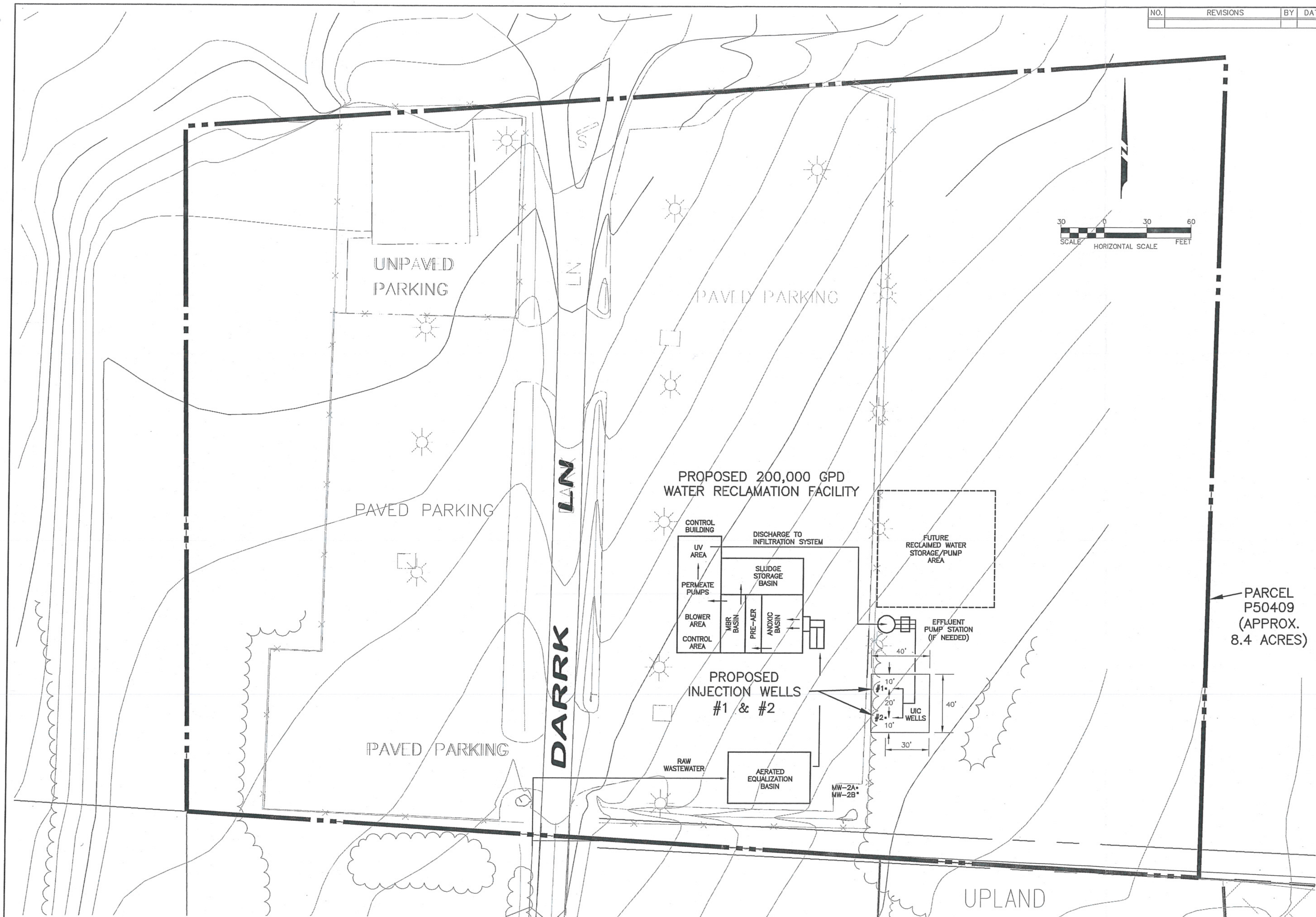
DESIGNED BY ---
DRAWN BY ---
CHECKED BY

UPPER SKAGIT INDIAN TRIBE
SKAGIT COUNTY WASHINGTON
WATER RECLAMATION FACILITY
WELL LOCATION MAP

DATE OCT. 2008
SCALE AS SHOWN
JOB NUMBER

SHEET 1 OF 2



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UPPER SKAGIT INDIAN TRIBE
SKAGIT COUNTY WASHINGTON
WATER RECLAMATION FACILITY
PROPOSED LAYOUT

DESIGNED BY --
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DATE OCT. 2008
SCALE AS SHOWN
JOB NUMBER

SHEET 2 OF 2

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DEC - 8 2008
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December 4, 2008

VIA REGULAR MAIL

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DEC - 6 2008
U.S. EPA REGION 10
OFFICE OF COMPLIANCE AND ENFORCEMENT

Ms. Jennifer Parker
Ground Water Unit
U. S. Environmental Protection Agency, Region 10
1200 Sixth Avenue, Suite 900, OCE-082
Seattle, Washington 98101
Phone: 206–553-1900

Re: Upper Skagit Indian Tribe, Proposed Water Reclamation Facility
Pre-Design Report

Dear Ms. Parker:

As we discussed earlier, attached are two copies of the draft Pre-Design Report (dated December 3, 2008). Please feel free to provide comments and suggestions as we move forward and finalize this report.

In addition it is noted that based on the October 3, 2008 Subsurface Injection Evaluation, the bottom of the proposed injection wells will be located so that there will be 40 ft. vertical and 600 ft. horizontal separation (minimum) to edge of the nearest aquifer. Also, the bottom of the proposed injection wells will be located with a minimum of 20 ft. vertical separation to the top of the nearest confining layer (Olympia Nonglacial Sediments). Associated Earth Sciences, Inc. has indicated that they would happy to discuss this information in more detail with you if needed.

Please do not hesitate to call if any additional information is needed.

Sincerely,
Wilson Engineering, LLC

Jeffrey G. Christner

Jeffrey G. Christner, P.E.

cc: Bob Hayden, Corporate Project Manager, Upper Skagit Indian Tribe, 5984 N. Darrk Lane, Bow, WA 98232 (include one copy of the 12/3/08 Pre-Design Report)

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Upper Skagit Indian Tribe
Bow Hill Road Reservation

WASTEWATER TREATMENT FACILITY PRE-DESIGN REPORT

PRELIMINARY

WILSON ENGINEERING, LLC

Consulting Engineers
805 Dupont Street, Suite #7
Bellingham, Washington 98225

December 3, 2008

Project # 2007-101

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EXECUTIVE SUMMARY

The Upper Skagit Indian Tribe ("USIT" or "Tribe") is planning future development on the Bow Hill Road Reservation. To serve this planned development, the Tribe is evaluating the option of constructing a new wastewater treatment facility to serve Tribal connections on the Bow Hill Road Reservation. Currently, the Tribe's wastewater is pumped to the Burlington force main (routed along Old Highway 99) which is maintained by Samish Water District. The existing sewer connection is not adequate for future sewer demands and, in light of this; the Tribe is researching other wastewater treatment options.

The preferred option is to design and build an on-site wastewater treatment facility which will serve existing and future Tribal connections, allowing development of the Skagit Resort area. In addition, the facility will use a membrane bioreactor treatment process and effluent will be treated to Class A Reclaimed Water Standards. The proposed location for the wastewater treatment facility and discharge is on Tribal trust land, see Figure 1 – Overall Site Layout. The primary reasons for switching from the Burlington force main to a new on-site treatment facility are as follows:

- Wastewater will be treated to a higher standard then currently treated at the Burlington Wastewater Treatment Plant.
- The Tribe will have the ability to reuse the reclaimed water (treated effluent) for beneficial purposes, such as flushing toilets, irrigation, etc.
- Raw wastewater is less likely to leak out of an on-site treatment system, minimizing pollution concerns. The Burlington WWTP is over 7 miles away.
- The Tribe will not need to invest the capital needed to improve the existing Burlington force main connection. It was estimated that 3000 feet of 8" sewer pipe would need to be replaced along a remote 20' wide easement with challenging work conditions (slopes greater then 20%).
- The Tribe will no longer be responsible for operation and maintenance costs associated with the existing Burlington force main connection.

The Tribe has evaluated discharge options, and after several months of hydrogeological investigations, it has been concluded that the most feasible design includes injection of reclaimed water into a permeable geologic unit below the surface. The October 3, 2008 Subsurface Injection Evaluation Technical Report provides the results and recommendations for our proposed discharge method.

The proposed design discharge parameters for wastewater constituents of concern are compliant with EPA Primary Drinking Water Standards. The proposed treated effluent will meet the following design standards:

- $BOD_5 \leq 5$ mg/L
- $TSS \leq 5$ mg/L
- Turbidity ≤ 0.2 NTU, as a monthly average

- Total Coliform = Non-detect, as a post filtration UV performance design criteria
- Total Nitrogen ≤ 10 mg/L

Also EPA's Class V UIC Study Fact Sheet and the proposed Inventory of Injection Wells (EPA Form 7520-16) are included in Appendix A. Two Class V (Type 5D) injection wells are proposed, each one sized to handle the 20-YR build-out flow projection (200,000 gpd – Average Daily Flow). Proposed wells will be constructed and pilot tested after obtaining approval from the EPA. If pilot test results are favorable, as anticipated, the Tribe will then be able to move forward with final design of the proposed Water Reclamation Facility.

200,000 gpd = 6 million gal / month!

SECTION 1 – INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of this report is to evaluate the design issues associated with construction of a new wastewater treatment facility for the Upper Skagit Indian Tribe's Bow Hill Road Reservation. The facility will be located on the Bow Hill Road Reservation. The end-product of this study is to determine the most feasible treatment and discharge alternatives and provide general design parameters for proposed facilities.

1.2 BACKGROUND

The Bow Hill Road Reservation sewer connections are currently pumped to the Burlington Force Main. The Force Main conveys raw sewage to the City of Burlington WWTP, located approximately seven miles south of the Bow Hill Road Reservation. The Upper Skagit Indian Tribe is preparing substantial development plans, and has reached a crossroad where a more feasible method of wastewater conveyance and treatment is desired. In addition, the Tribe is very interested in the beneficial uses of reclaimed water (i.e. groundwater recharge, Samish River drainage area recharge, irrigation, flushing toilets, etc.).

SECTION 2 – BASIC PLANNING DATA

2.1 LAND USE

Within northwest Skagit County, a broad mix of land uses can be found. This includes a variety of commercial/retail, public, and residential developments. The Upper Skagit Indian Tribe has numerous plans for development along the I-5/Bow Hill Road area. These plans include a new water park, new hotels, restaurants, retail, and a golf course. The proposed USIT developments will be phased in over the next 20 years. In fact, current plans suggest this development will occur most rapidly over the next 5 years (or so). An important component of the wastewater mix is the high concentration typically produced from casino/hotel complexes. An evaluation of the flows and loads are provided later in this report in Section 3.

2.2 TOPOGRAPHY

The USIT property near the proposed treatment facility site is fairly flat with gentle slopes ranging from 0% to 4%. Parcel P50409 surface elevations range from approximately 305 ft. on the northwest corner to 275 ft. on the southeast corner. The proposed treatment facility site is above the 100-year flood plain. See Figure 2 – Proposed Water Reclamation Facility Layout.

2.3 DRAINAGE BASINS

Storm water runoff from the parking lot on Parcel P50409 and adjacent land near Thousand Trails Campground is routed through drainage ditches and culverts to the southeast corner of the parcel. As flow moves east of the parking lot, it passes through a storm water retention pond. From the retention pond, runoff will generally sheet flow in an easterly direction toward Friday Creek. At this point, Friday Creek meanders in a southerly direction about 1.6 miles before draining into the Samish River.

2.4 GEOLOGY AND SOIL

Associated Earth Sciences, Inc. (AESI) observed the drilling of monitor wells (MW-1 through 3) and digging of exploration pits (EP-1 through 22) at the site. During these observations, AESI analyzed the near surface soils. Overall, the soils are likely suitable for construction of small concrete tanks and buildings, however, site specific exploration pits will need to be completed in the building footprint before any specific design recommendations can be made.

General Site Observations:

1. Moisture Sensitive soils. Native soils are likely suitable for use as structural fill, but only within 2% of optimum moisture contents. Significant drying/moisture conditioning will likely be required. Grading during the dry season is strongly recommended.
2. Standard Conventional Foundations. AESI's explorations did not indicate near surface conditions that would require deep foundation systems. Bearing capacities should be addressed as part of a site specific geotechnical investigation.
3. Foundation Preparation. Over excavation may be required to mitigate soft soils or soils with swell potential. We recommend site specific explorations (backhoe pits) to determine foundation subgrade conditions as part of a geotechnical investigation addressing the proposed development.
4. Foundation and Wall drainage. Due to the elevated silt contents and the poor infiltration properties of the near surface soils, foundation drains must be included as part of the development. Retaining walls, if included as part of development, will require "blanket drains" to relieve hydrostatic pressures behind the wall.

2.6 HYDROGEOLOGICAL CONDITIONS

Four monitor wells (MW-1, 2A, 2B, and MW-3) were drilled during the summer of YR-2008. During the drilling operation it was determined that surface soils consist of non-permeable silt material (Glaciomarine Drift Deposits), which extend approximately 60 ft. below surface at the proposed discharge site. Beneath the silt layer is a gravel/sand geologic unit (Vashon Advance Outwash) which extends from 60 ft. to 200 ft. (+/-) below surface. This geologic unit is highly permeable and is the preferred zone for rapid infiltration of treated wastewater effluent (Class A Reclaimed Water). Refer to the October 3, 2008 Subsurface Injection Evaluation Technical Report for additional information.

SECTION 3 – WASTEWATER FLOWS AND LOADINGS

3.1 CURRENT FLOWS

According to the Tribe's wastewater billing records, the current average day flow is 45,000 gpd. See existing connection and flow summary in Table 3-1 below.

TABLE 3-1 Current Flows

Existing Connections		Existing Average Daily Flows (gpd)
Casino:		17,000
Skagit Hotel:		18,000
Gas Station:		1,500
2 Residential + Hotel:		8,500
Existing Total:		**45,000**

3.2 FUTURE FLOWS

Future flows are anticipated to be brought on-line during Year-2010, Yr-2015, and thereafter. The future flows and connections over the next 20-years are summarized in Table 3-2 below.

TABLE 3-2 Future Flows

Future Connections		Future Average Daily Flows (gpd)
YR-2010 Connections		
4 Tenant Strip Mall:		4,000
Restaurant #1 (SE Corner):		6,000
Restaurant #2 (NW Corner):		6,000
Water Park:		70,000
YR-2010 Total:		86,000
YR-2015 Connections		
Golf Course:		40,000
YR-2015 Total:		40,000
Additional Connections		
Thousand Trails, WSDOT, etc:		29,000
Additional Total:		29,000
Future Total:		**155,000**

3.3 SAMPLING DATA

Tribal sampling data from March 2006 to October 2007 was compiled. The average strength measured from the casino pump station calculates to approximately 555 mg/L BOD_5 and 512 mg/L TSS.

In addition a grab sample was taken from the casino pump station on October 17, 2007. The Total Kjeldahl Nitrogen (TKN) was reported to be 50 mg/L. Sampling data is compiled in Appendix B – Raw Sewage Sampling Data.

3.4 PROJECTED WASTEWATER LOADINGS

Based on our sampling results, the TKN strength is projected to be 50 mg/L for all hotels, casinos, and restaurants. The existing and future connections have been assigned loading concentrations based on the assumptions provided below.

TABLE 3-3 Flow and Load Summary (Yr-2008 to Yr-2028)

Connections	Avg. Daily Flow (gpd)	Avg. Daily Loads (mg/L)		
		TSS	BOD	TKN
Existing (Yr-2008) Connections				
Casino:	17,000	512	555	50
Skagit Hotel:	18,000	512	555	50
Gas Station:	1,500	512	555	50
2 residential + hotel:	8,500	300	300	40
Existing Total:	45,000	**472**	**507**	**48**
YR-2010 Connections				
4 Tenant Strip Mall:	4,000	300	300	40
Restaurant #1 (SE Corner):	6,000	512	555	50
Restaurant #2 (NW Corner):	6,000	512	555	50
Water Park:	70,000	512	555	50
YR-2010 Total:	86,000	**502**	**543**	**50**
YR-2015 Connections				
Golf Course:	40,000	300	300	40
YR-2015 Total:	40,000	**300**	**300**	**40**
Additional Connections				
Thousand Trails, WSDOT, etc:	29,000	300	300	40
Additional Total:	29,000	**300**	**300**	**40**
YR-2028 Total =	200,000	426	451	46

In summary, the Yr-2028 build-out raw wastewater characteristics are projected to be approximately 450 mg/L BOD_5, 450 mg/L TSS, 50 mg/L TKN, and 200,000 gpd average day flow.

SECTION 4 – ALTERNATIVES

4.1 WASTEWATER TREATMENT ALTERNATIVES

Wastewater treatment alternatives include the following:

- Alternative I - Membrane Bioreactor (MBR) Treatment System
- Alternative 2 - Conventional Activated Sludge Treatment System

Conventional treatment systems utilize activated sludge to treat incoming waste. There are several types of conventional activated sludge systems, including traditional systems, sequencing batch reactors (SBRs), oxidation ditches, and proprietary plants (such as Parkson's Biolac System).

Membrane bioreactors (MBR's) do share many of the plant operational features associated with conventional activated sludge plants. These include high mixed liquor suspended solids (MLSS) concentrations and high solids residence times (SRTs). The difference, however, is that in the case of MBRs, these operational parameters are higher than the typical ranges used in conventional activated sludge systems. The ability of a MBR to operate at higher concentrations allows for a smaller treatment basin footprint when compared to conventional activated sludge footprints.

MBRs are able to operate with higher SRTs and MLSS concentrations due to their means of separating solids from treated effluent. The MBR utilizes micro or ultra filtration to extract effluent directly from the bioreactor through a membrane with pore sizes ranging from 0.04 to 0.4 micrometers. As a result, a MBR provides secondary and tertiary treatment in a combined process. Another result is that a MBR can efficiently operate over a wide range of SRTs and MLSS concentrations. This helps simplify operation of the biological treatment process. However, treatment staff must learn how to monitor and manage a comparatively complex array of operational parameters related to the membranes. This includes the membrane flux rate, transmembrane pressure, air scouring, mixed liquor recycle rates, and periodic membrane cleaning. Management of these operational parameters is typically automated. Still, a knowledgeable operator is required to recognize and promptly correct problems when they occur.

In contrast, conventional extended aeration plants rely on settlement to separate the solids from treated effluent. The result is a secondary treated effluent. While the high SRT and MLSS parameters associated with extended aeration provide excellent treatment, allowing them to get too high reduces solids settleability and degrades the final effluent. A highly trained operator skilled at managing the biological treatment process is essential. The operator must monitor the activated sludge process closely and consistently make adjustments to assure adequate solids settling. The operator interaction with the plant is typically more frequent than with an MBR.

MBRs are relatively new treatment systems in the United States; however, MBR technology has been used in other countries for more than 20 years. In addition, MBRs have been selected for numerous projects located in Washington State Indian country since 2002. The first of which was the Tulalip's Enviroquip MBR, which was placed on-line during the summer of 2003. Since then, the Chehalis, Lummi, Stillaguamish, Swinomish, Squaxin, and Yakama reservations have constructed MBR treatment plants. In addition, the Washington State Department of Ecology added a chapter in 2006 which is dedicated to MBR Treatment Systems to their *Criteria for Sewage Works Design*. This chapter (T6 Membrane Bioreactor Treatment Systems) provides a more detailed overview of these systems and is included as a reference in Appendix C.

The following is a list of advantages and disadvantages for MBR versus conventional activated sludge treatment plants.

Membrane Bioreactor Treatment Plant

Advantages:

1. Higher volumetric loading rate resulting in a smaller footprint.
2. More reliable high quality effluent based upon turbidity, bacteria count, TSS, BOD, and TKN.
3. Able to achieve non-detect for total coliform and 0.2 NTU turbidity levels, meeting Class A Reclaimed Water Standards and Primary Drinking Water Standards.
4. Established operational track record in other countries.
5. Odor control is typically not needed at MBR facilities.

Disadvantages:

1. Higher operational cost.
2. Need to control membrane fouling.
3. More mechanical equipment and higher associated life-cycle cost.
4. Need higher certification level for wastewater operator.
5. Hydraulic peak capacity is typically limited to two times average capacity.

Conventional Activated Sludge Treatment Plant

Advantages:

1. Lower operational cost.
2. Established operational track record in the USA.
3. Fewer mechanical components and lower associated life-cycle costs.

Disadvantages:

1. Lower volumetric loading rate resulting in a larger footprint.

2. Less reliable high quality effluent based upon turbidity, bacteria count, TSS, BOD, and TKN.
3. Not able to achieve Class A Reclaimed Water Standards and Primary Drinking Water Standards without additional treatment (including filtration and coagulation treatment units).
4. More frequent certified operator process monitoring required.
5. Odor control may be more of an issue.

Typical flow process diagrams and wastewater treatment plant layouts are provided for both conventional activated sludge and MBR treatment systems in Appendix D. Typically the selection between these two treatment alternatives would be based upon capital cost, O&M cost, and specific needs. These items are evaluated in Section 5.

4.2 EFFLUENT DISPOSAL ALTERNATIVES

The effluent disposal alternatives include the following:

- Alternative 1 – Discharge to Surface Water
- Alternative 2 – Discharge to Ground (surface infiltration)
- Alternative 3 – Discharge to Ground (subsurface injection well)

These alternatives and the associated complexity with permitting & scheduling are summarized in Appendix E.

<u>Alternative 1 – Discharge to Surface Water</u>

A surface water discharge to either Friday Creek or Samish River will involve construction of an outfall off of the Reservation, and associated easements and approvals. Obtaining a new surface water discharge permit is a complex and time consuming task and, depending on the circumstances, can required unusual and highly expensive treatment processes. All surface water discharges to waters of the State of Washington must have an approved NPDES permit obtained from the Department of Ecology.

Concerns associated with surface water discharges include temperature, metals, dissolved oxygen, fecal coliform, and ammonia.

Salmon and trout spawning streams, especially those listed as Core Summer Salmonoid Habitat (such as Friday Creek & Samish River), are very sensitive to warm temperature discharges. According to the DOE WRIA 3 dated November 8, 2006, the highest 7-DADMax (7-day average of the daily maximum temperatures) allowed is 16°C (60.8°F) for Friday Creek and Samish River. In addition, the proposed spawning and incubation criteria is 13°C (55.4°F) from February 15 to June 15. Cooling facilities will be required for treated wastewater discharges at these locations. It is anticipated that required cooling facilities will need both evaporation and refrigeration equipment. Both or which are expensive and have substantial O&M requirements.

Facilities for removing heavy metals from municipal wastewater are expensive and rare. The typical solution is to move the discharge point to a water body which supplies the required dilution. In addition, some communities are able to solve metal problems by locating and reducing metal discharge sources from drinking water systems. The most common metals are copper, zinc, and lead (from copper piping, galvanized piping, and lead solder). These metals are toxic, even in trace amounts, to salmon. The calculated dilution required for metals (sampled on 10/17/2007) range from 29 CFS to 133 CFS depending on water hardness assumptions. Even if we determine that Friday Creek's hardness is very low (hardness = 20 or less) and our actual dilution requirement calculates out to 20 +/- CFS, we still have an unpermittable discharge point. Friday Creek's 7-day 10-year low flow event is less then 5 CFS. The lack of dilution available in Friday Creek is a substantial concern, and, at this time it eliminates the option of discharging to Friday Creek. See Appendix G – Metals in Wastewater.

Dissolved oxygen can be added to wastewater effluent via cascade aeration and/or mechanical aeration. For waterways listed as core summer salmoid habitat, the lowest 1-day minimum dissolved oxygen criteria is 9.5 mg/L, and a substantial investment in aeration equipment will be required to achieve this criteria.

Fecal removal is accomplished through disinfection, and the most common technology used today is ultraviolet disinfection.

Alternative 2 – Discharge to Ground (surface infiltration)

A surface infiltration discharge involves construction of some type of on-site surface percolation system. This option is very favorable since permitting is typically a straight forward process through the EPA when it is located on tribal trust land. The challenge at the Bow Hill Road site is the thick layer of impermeable material located at the surface. AESI performed an on-site surface infiltration evaluation which is presented in Appendix F – February 20, 2008 Potential Wastewater Infiltration Evaluation. After exploring the available portions of the Tribe's property, it was determined that some infiltration may be performed on the far east side next to Old Highway 99; however, capacity will be limited to surface infiltration rates of 80,000 gpd or less. This available capacity is significantly less then the future projection of 200,000 gpd (ADF), and eliminates the option of discharging solely to surface infiltration.

Alternative 3 – Discharge to Ground (subsurface injection well)

A subsurface injection well discharge involves construction of a well with a screen located in a permeable geologic unit. In this case, the screen will need to be located beneath the impermeable silt layer, which extends from the surface to a depth of approximately 60 feet down. A subsurface injection well detail (also referred to as a discharge well or dry well) is included as Figure 4 in this report. The permitting authority for this option will also be the EPA, when discharge is located on tribal trust land. After chatting with the EPA's Ground Water Unit in January 2008, it was stated that the permitting process will require favorable hydrogeological investigation results and wastewater constituents of concern are to be treated to primary drinking water standards. In addition, the local well head protection zones are to be identified, so that an injection well site can be located outside of existing well head protection zones. After the EPA finalizes their review for this proposed discharge, a determination will be made if discharge will be permitted by rule without monitoring requirements or permitted by rule with monitoring requirements.

The Inventory of Injection Well form was submitted to the EPA on October 6, 2008. The subsurface injection well investigation is summarized in AESI's October 3, 2008 Subsurface Injection Evaluation Technical Report. This report was also provided to the EPA on October 6, 2008.

SECTION 5 – RECOMMENDATIONS

5.1 RECOMMENDED TREATMENT ALTERNATIVE

The MBR is the recommended treatment alternative. The advanced wastewater treatment capability will help reduce the risk of injection well failure. In addition, the requirement to treat to primary drinking water standards makes the MBR the simplest and most reliable process configuration for this application.

While an activated sludge treatment plant can provide excellent treatment, plant upsets open up the possibility of discharging high solids levels and effecting the injection wells performance. MBR's physical barrier between the treatment process and the injection well provides a high level of system reliability. In addition, the USIT plans future reuse of the reclaimed water. MBRs are well suited for achieving reuse standards.

In addition to the disposal facilities mentioned above, the decision to construct a wastewater treatment facility also requires the construction of new wastewater collection facilities. The analysis for collection and disposal facility alternatives is incorporated into the proposed facilities discussion below.

Wilson Engineering and USIT staff visited three local wastewater facilities during the preliminary design of the recommended alternatives. A summary of these MBR facilities are included in Section 6 under Table 6-1.

5.2 RECOMMENDED EFFLUENT DISCHARGE ALTERNATIVE

Alternative 3 – Discharge to Ground (subsurface injection well) is the preferred discharge method. The surface geologic unit is mostly impermeable and is not suitable for our design flows. Surface water discharge presents permitting challenges associated with temperature standards and metal concentrations.

SECTION 6 – PROPOSED FACILITIES

6.1 TREATMENT FACILITY DESIGN NARRATIVE

Wastewater treatment will be completed by a membrane bioreactor (MBR) treatment facility. In addition, the MBR facility shall produce an effluent that will meet the requirements for the State of Washington Class A reclaimed water. Also, the MBR facility shall meet the redundancy and reliability requirements for an EPA Reliability Class II facility as defined in the State of Washington Department of Ecology Criteria for Sewage Works Design. Redundant mechanical equipment such as pumps and blowers shall be provided. A minimum of two biological basins and two membrane basins shall be provided.

Class A reclaimed water requirements will be met.

The selected site for the treatment facility is on parcel P50409 (Section 31, T 36N, R 04E) at the remote parking area for the Skagit Resort. This is tribal trust land located north of the Skagit Casino. The site has power, water, and lighting available. This site was selected for the following primary reasons:

1. Close proximity to the pump station force main discharge.
2. Parcel P50409 is tribal trust land.
3. Discharge well can be located adjacent to wastewater treatment facility.
4. If an overflow to the Burlington WWTP is needed, the existing 8" gravity sewer is located nearby (on the south side of this site).

6.2 PRELIMINARY TREATMENT

Appropriate preliminary treatment is important to the function of all wastewater treatment facilities, but especially MBRs. Preliminary treatment removes objectionable material such as grit and stringy material that damage the membranes. For this treatment facility, preliminary treatment will include flow equalization with aeration and fine screening.

The first preliminary treatment unit will be an aerated flow equalization basin. A flow equalization basin provides storage for high flow events. The equalization basin will dampen these flow spikes and reduce peak load on downstream facilities. In addition, the equalization basin will provide storage for wastewater flow that exceeds the max plant capacity. This would most likely occur during a busy hotel/casino weekend or an unexpected I/I event. The majority of the collection system will be new construction, so extreme I/I problems are not anticipated. The excess flow can be stored in the equalization basin and treated after high flows are subsided. The wastewater arriving at the plant may be septic due to detention times in the collection system. Aerating the wastewater in the flow equalization basin will provide odor control.

The equalization basin will be a covered reinforced concrete tank partially or completely buried. The tank should be covered as an odor control measure and to improve plant appearance. Venting the tank through a pipe up into the air should help limit noticeable odors in the area. In addition, a small amount of mixed liquor can be returned to the equalization basin for additional odor reduction, if needed. The equalization basin should, as a minimum, have sufficient capacity to store one average day of future flow. This storage will allow operational flexibility if plant unit(s) need to be taken off-line for emergency repair or maintenance. The Yr-2028 average day design plant capacity is 200,000 gpd, and we anticipate a Yr-2028 peak 24-hour plant capacity of 400,000 gpd. If flow data ultimately indicates that I/I is a major problem during wet weather, and our assumptions are not conservative enough, then additional equalization volume can be constructed on an as-needed basis prior to Yr-2028. To complete the preliminary design, Wilson Engineering, LLC assumed these parameters will be sufficient for equalization basin sizing. The final size of the basin will need to be re-confirmed during final design when the impact of future sewer systems and I/I problems are addressed in more detail.

one day of flow storage

Wastewater will be pumped out of the equalization basin to downstream treatment processes. The total pumping capacity should equal the peak day capacity of the wastewater treatment plant. Based on the 400,000 gallon peak design capacity, a combination of pumps delivering approximately 280 gpm is required. To provide redundancy, multiple pumps will be provided with capacity to pump 280 gpm with the largest pump out of service.

The next preliminary treatment unit will be a mechanical fine screen. A mechanical fine screen is designed to remove small particles from the wastewater and is critical to protecting the membranes. The screen is to be self-cleaning and to be designed to automatically wash, compact, and transport the captured material to a receptacle for disposal. Washing the screenings to remove fecal material simplifies later disposal of the screened material. Fine screens will be provided with openings recommended by the selected MBR manufacturer.

Finally, the preliminary treatment design will include room for the installation of coarse screening and mechanical grit removal units, if needed for future flexibility.

6.3 FLOW METERING

Flow metering provides important information and is essential to making plant operational decisions. It will be particularly important for monitoring inflow and infiltration (I/I). Through daily monitoring, I/I problems can be promptly identified and addressed. Metering will be provided either upstream or downstream of the equalization basin. An in-line flow meter that measures closed conduit flow is recommended. The flow meter will be tied into the treatment plant control system. The flow metering system will be capable of recording and storing instantaneous flow rate and totalized flow data.

6.4 TREATMENT

Wastewater will flow from the equalization/screening units directly to the MBR treatment process. The process associated with the MBR system is provided in Section 4.0 of this report. The detailed design of the MBR will be completed during final design phase with assistance from a selected MBR system manufacturer. In addition, this design is structured so that a future expansion can be easily incorporated into the proposed layout. See Figure 3 – Water Reclamation Facility Future Expansion Layout.

MBR system not designed yet

MBR facilities were visited on January 11, 2008. The three facilities are Tulalip (Quil Ceda Village), Stillagaumish (Angel of the Winds), and Swinomish (Northern Lights). A facility comparison is provided in Table 6-1 below. It should be noted that all of these facilities have Enviroquip's Kubota flat plate membranes. During the site visits it was discovered that odor control was not needed and was not provided at any of these facilities.

TABLE 6-1

MBR Facility Comparison (Site Visit - January 11, 2008)			
	Tulalip (Quil Ceda Village)	**Stillagaumish (Angel of the Winds)**	**Swinomish (Northern Lights)**
Plant Capacity	200,000 gpd (current) / 4 mgd (future)	50,000 gpd (current)	50,000 gpd (current)
Odor Control Facilities	None	None	None
Sludge Facilitites	Contract to haul sludge off-site (current). Dewater & Dry on-site (future)	Contract to haul sludge off-site	Contract to haul sludge off-site
Operations	1 Operator - in house	Remote Contract Operations (Water & Wastewater Services Inc.)	Remote Contract Operations (Water & Wastewater Services Inc.)
Effluent Discharge Method	To Ground (Current) Reuse (Future)	Reuse (toilet flushing at Casino) and To Ground	To ground (current) Ocean Outfall (future)

6.5 DISINFECTION

Disinfection is provided to achieve drinking water standards. Ultraviolet disinfection is selected as it is effective and has low O&M requirements.

6.6 EFFLUENT DISPOSAL

Treated effluent will be continuously discharged to one of the on-site injection wells. Redundancy is planned, so that one well will serve as a stand-by unit while second well receives design flows. Design flows include peak day demands through Yr-2028. The underground injection well details are provided in AESI's October 3, 2008 Subsurface Injection Evaluation Technical Report.

6.7 WASTE ACTIVATED SLUDGE

Waste activated sludge (WAS) is the active biomass removed from a treatment plant process. The biomass is commonly called the mixed liquor. WAS is removed to maintain the mixed liquor suspended solids (MLSS) concentration within operating parameters. At small treatment plants just under our size range, it is typically most cost effective to temporarily store the WAS. Then, as needed, a septic sludge hauler can remove and transport the WAS to a solids handling facility for further treatment and disposal. However, our future average day flow of 200,000 gpd puts us into a size range where it is typical to evaluate the cost savings associated with thickening equipment. Additional solids removal such as dewatering and drying are usually not cost effective for facilities with flows below 1 million gallons per day. However, dewatering and drying can be revisited and further evaluated during final design.

Assuming the waste activated sludge is discharged to a sludge holding tank and decanted to 1.5% solids, the projected volume of sludge produced is estimated as follows:

Current Average Day Sludge Production = 6,300 gallons/week
Future (Build-Out) Average Day Sludge Production = 28,000 gallons/week

If the Tribe chooses to install Enviroquip's PAD-K thickening equipment in the sludge holding unit, the sludge can be thickened to 3.0% solids. At 3.0% with additional volatile solids reduction, the projected volume of sludge produced is estimated as follows:

Current Average Day Sludge Production = 2,400 gallons/week
Future (Build-Out) Average Day Sludge Production = 10,500 gallons/week

See detailed biosolid calculations and assumptions in Appendix H – Sludge Production Calculations.

6.8 INSTRUMENTATION AND CONTROLS

Due to the mechanical nature of the MBR plant, automatic operation is essential. Also, in order to allow the option for future wastewater reuse, extensive plant instrumentation is required. The instrumentation will monitor all treatment facility operations. In the event an operation should fail, the controls will sound an audible alarm and notify a dedicated phone list of the problem. In addition, if it is a critical operation failure associated with high turbidity readings (which will be reported continuously), the permeate pumps will automatically stop and effluent will not flow to the underground injection wells. In addition, the equalization basin will begin storing wastewater. Wastewater will be stored until failure is corrected.

The treatment plant instrumentation and controls should be designed to provide the following monitoring and alarm functionality:

1. Primary power source failure
2. Equalization basin high liquid level
3. Equalization pump failure

4. Mechanical screen failure
5. Dissolved oxygen level in anoxic and aerated zones
6. Aeration mechanical failure
7. MBR equipment failure
8. MBR transmembrane pressure
9. MBR basin high liquid level
10. Disinfection equipment failure
11. High effluent turbidity
12. Underground injection well high liquid level

The entire facility will be automatically controlled by a programmable logic controller (PLC). The controller will carry out automatic operations, log and store important data, and initiate telephone alarm notifications. In addition, SCADA equipment and telemetry can be included for monitoring collection system pump stations and treatment plant units. SCADA adjustments to the collection system pump stations are to be coordinated with Samish Water District (SWD), since pump stations are currently monitored and maintained by SWD.

6.9 STANDBY POWER GENERATION

The facility will have a dedicated standby diesel power generator with an automatic transfer switch. The standby power system will monitor incoming power, and in the event of a power failure, automatically start and begin powering the facility. An outdoor air cooled unit with acoustical enclosure is proposed.

6.10 BUILDING AND SHELTERS

It is proposed that the lab area, controls, pumps, and UV equipment will be housed in a building. An existing metal building is located on the west side of the parking lot, and to keep a similar cost effective style, a new rigid frame metal building is proposed. In addition, optional metal building shelters can be located over the MBR process tanks. If shelters are selected, clearance issues and permanent hoisting equipment will need to be carefully considered during the final design effort.

6.11 COST ESTIMATE

Two preliminary cost estimates are provided for planning purposes. These are Construction Costs and Operation & Maintenance (O&M) costs.

The construction cost estimate is broken into three components which are as follows:

1. MBR Water Reclamation Facility ($2,587,000)
2. Reclaimed Water Distribution & Infiltration System ($144,000)
3. Additional Options ($622,000)

In addition, the estimate includes design phase engineering and construction phase engineering services. The total estimate for all three components equals $4,124,000. See detailed cost breakdown in Appendix I – Cost Estimate Information.

O&M costs for the proposed water reclamation facility are also provides in Appendix I. These costs include biosolids, maintenance & repair, membrane replacement, power, contract operation, and miscellaneous items. The projected average monthly O&M cost without sludge thickening is $27,000 per month. In comparison, the projected average monthly O&M cost with sludge thickening is $20,000 per month (a difference of $84,000 per year).

The budgetary construction cost for the PAD-K sludge thickening system is $315,000; however, when contingencies and engineering are included the budgetary cost for PAD-K sludge thickening equipment increases to $426,195. The break even point for thickening equipment is approximately 5 years (at build-out demand), and the Tribe should evaluate the associated benefits. One benefit to note is that there will be less haul truck traffic at the Skagit Resort, since we estimate that thickening will reduce the total sludge quantity by approximately 60%.

SECTION 7 – MONITORING REQUIREMENTS

7.1 PROPOSED MONITORING PLAN

The proposed monitoring requirements consist of items identified in the 1997 DOH & DOE Water Reclamation and Reuse Standards. In addition the compliance requirements are to be sufficient to meet Class A Reclaimed Water standards utilizing a membrane bioreactor treatment process.

Say they'll monitor to meet State of WA requirements for Class A Reclaimed Water but some of the effluent mon. is not included.

These monitoring requirements are summarized in Table 7-1 and Table 7-2 on the following pages.

TABLE 7-1 Proposed Monitoring Requirements for Treated Effluent

Parameter	Sample Type & Frequency	Compliance Requirements
Biochemical Oxygen Demand (BOD)	24-hour composite, collected at least weekly	Shall not exceed 5 mg/L, determined monthly, based on the arithmetic mean of all samples collected during the month.
Total Suspended Solids (TSS)	24-hour composite, collected at least daily	Shall not exceed 5 mg/L, determined monthly, based on the arithmetic mean of all samples collected during the month.
Total Nitrogen as N	24-hour composite, collected at least weekly	Shall not exceed 10 mg/L (as N), average determined annually, based on the arithmetic mean of all samples collected during previous 12 months.
Total Coliform	Grab, collected at least daily	1/100 mL median value determined daily based on bacteriological results of the last 7 days for which analyses have been completed; 5/100 mL maximum.
Turbidity	Continuous recording turbidimeter	Filtered wastewater shall not exceed an average operating turbidity of 0.2 NTU, determined monthly, and no more than 5% of the monthly readings exceed 0.5 NTU. Turbidity may not exceed 1 NTU.
Dissolved Oxygen	Grab, collected at least daily	Shall contain dissolved oxygen

TABLE 7-2 Proposed Monitoring Requirements for Ground Water from Monitoring Wells No. 1 and No. 3

Parameter	Sample Type & Frequency	Compliance Requirements
TOC	Grab, collected at least quarterly	Not specified
Primary contaminants, secondary contaminates, radionuclides, and carcinogens listed in chapter 173-200 WAC.	Grab, collected at least quarterly	Not specified

SECTION 8 – CONTINGENCY PLAN

8.1 PROPOSED CONTINGENCY PLAN

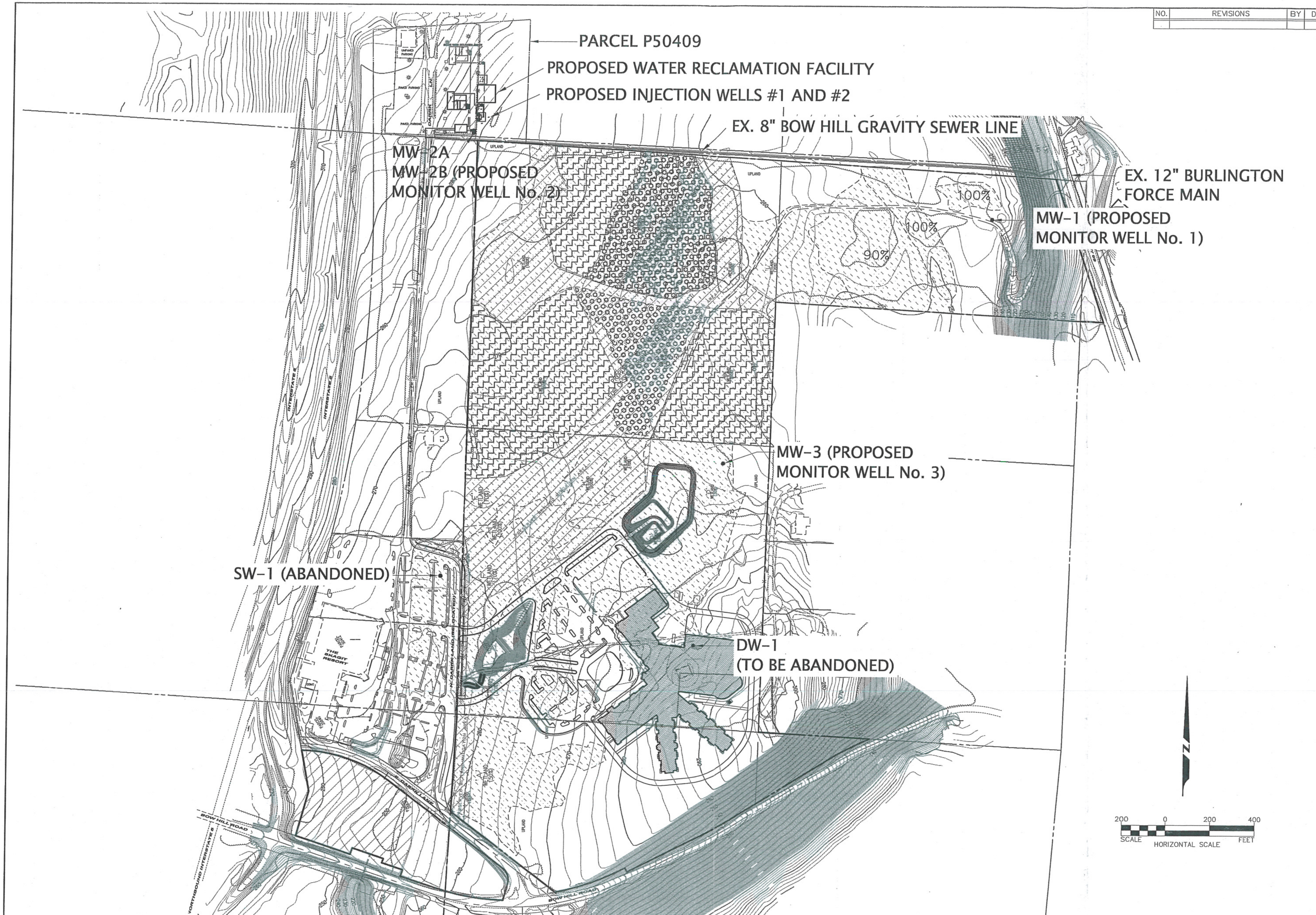
The proposed discharge strategy is to route treated wastewater effluent into an on-site discharge well. In the future, other reuse options (such as irrigation and toilet flushing) will be evaluated in more detail. The treated effluent will be monitored per the Monitoring Plan. The treated effluent is to meet Class A Reclaimed Water standards. In addition, redundancy and reliability measures are to be included per Department of Ecology's Criteria for Sewage Works (Chapter E1). If it is determined that the treated effluent is failing to achieve requirements as outlined in the proposed Monitoring Plan, a critical operation failure is to be alarmed, and flow to the discharge well(s) is to be halted.

In addition, a turbidity reading greater than 1 NTU is to initiate an automatic critical operation failure alarm, which will shut down permeation until problem is corrected. Operation personnel will have a window of time to correct the treatment problems. The window of time will be equal to the equalization basin fill time. It is suggested that the equalization basin be sized to store the volume of one future average day flow (200,000 gallons), allowing such time to identify and fix the problem. If the equalization basin fills to the high alarm level and if the treatment problems have not been corrected, the equalization basin will overflow to the original 8" gravity sewer and continue downstream to the Burlington WWTP.

It is suggested that the Tribe and Samish Water District maintain an emergency overflow agreement, allowing connection only during the unlikely emergency event (critical operation failure) as discussed above.

When treatment problems have been successfully corrected, plant failure alarm is to be reset and flow may be directed back to the discharge injection wells.

FIGURES



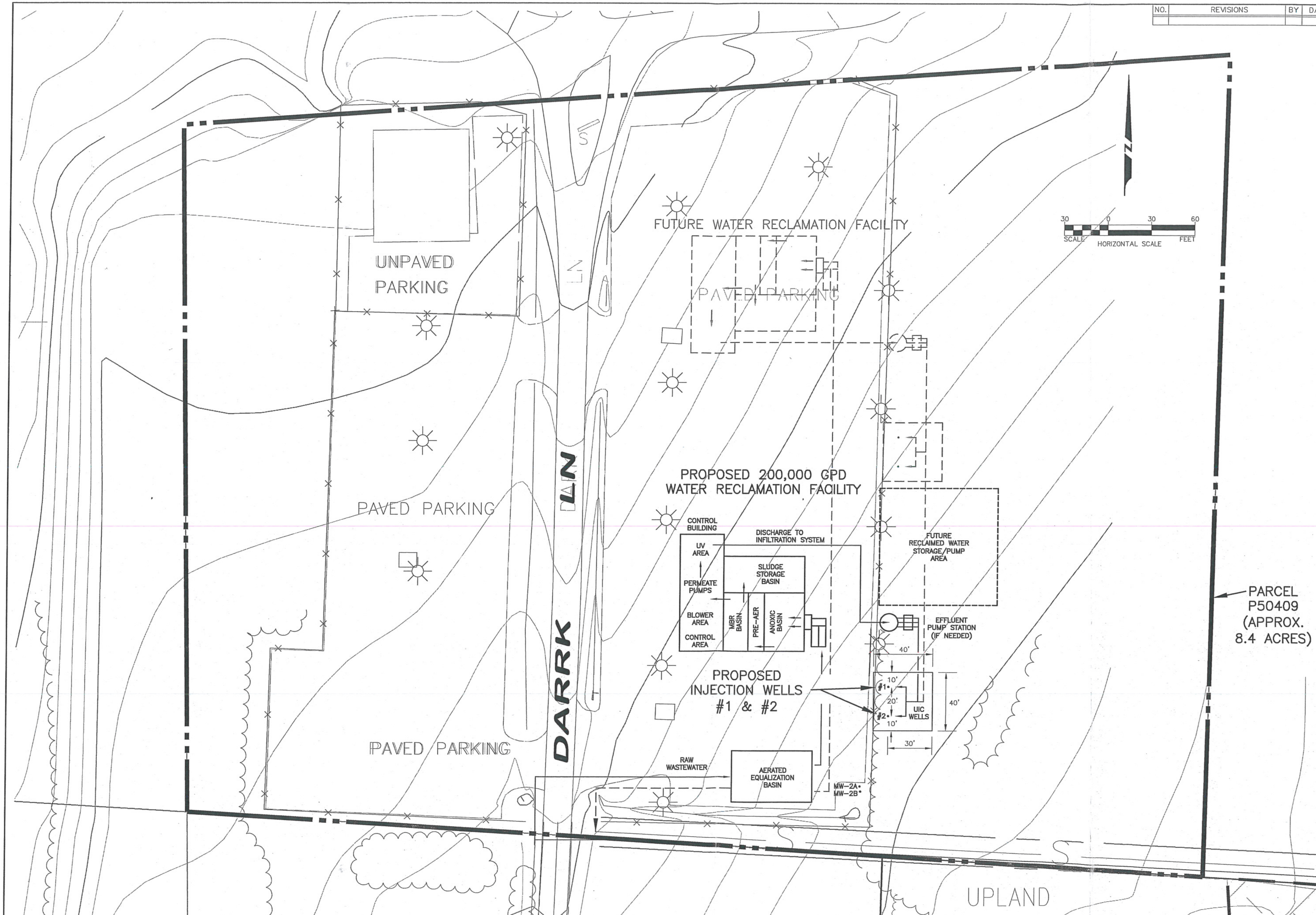
NO.	REVISIONS	BY	DATE

WILSON ENGINEERING, LLC
805 DUPONT STREET
BELLINGHAM, WA 98225
(360) 733-6100 • FAX (360) 647-9061
www.wilsonengineering.com
Wilson
SURVEY/ENGINEERING

DESIGNED BY --
DRAWN BY --
CHECKED BY

UPPER SKAGIT INDIAN TRIBE
BOW HILL ROAD RESERVATION
WATER RECLAMATION FACILITY
Figure 1 - Overall Site Layout

DATE NOV. 2008
SCALE AS SHOWN
JOB NUMBER 2007-101
SHEET 1 OF 1



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UPPER SKAGIT INDIAN TRIBE
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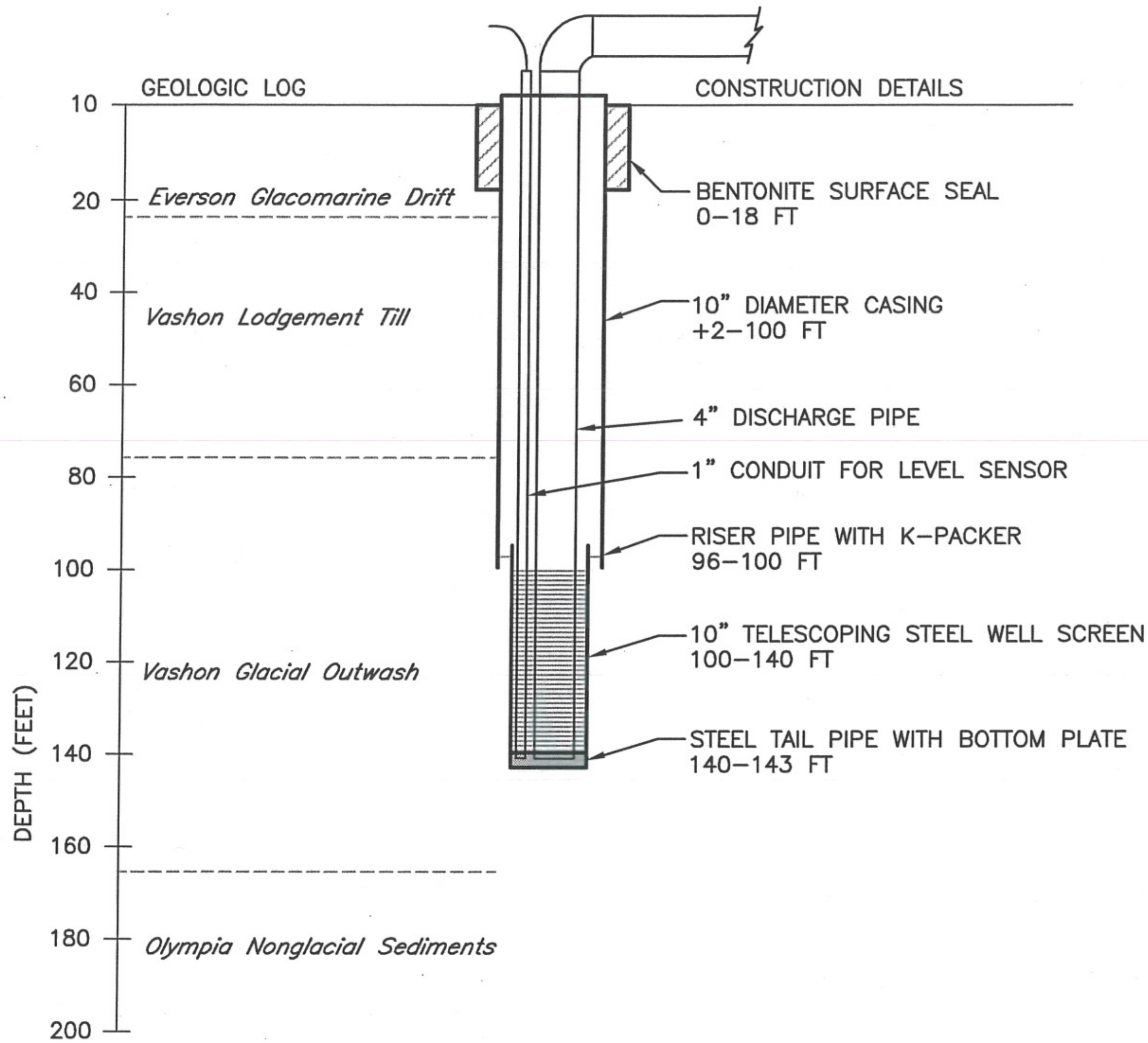
WATER RECLAMATION FACILITY
Figure 3 – WRF Future Expansion Layout

DATE NOV. 2008
SCALE AS SHOWN
JOB NUMBER 2007-101
SHEET 1 OF 1



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UPPER SKAGIT INDIAN TRIBE	DATE 11/19/08	SHEET 1
BOW HILL ROAD RESERVATION	SCALE nts	OF
WATER RECLAMATION FACILITY Figure 4 – Discharge Well	JOB NO. 2007-101	1

APPENDIX A

APPENDIX A
EPA CLASS V UIC STUDY FACT SHEET AND PROPOSED INVENTORY OF INJECTION WELLS

CLASS V UIC STUDY FACT SHEET
SEWAGE TREATMENT EFFLUENT WELLS

What is a sewage treatment effluent (STE) well?	Class V STE wells are used for the shallow disposal of treated sanitary waste from publicly owned treatment works or treated effluent from a privately owned treatment facility that receives only sanitary waste. In addition to being used for the purpose of wastewater disposal, STE wells are commonly used where injection will aid in aquifer recharge or subsidence control, or to prevent salt water intrusion.
What types of fluids are injected into STE wells?	Fluids generally subjected to secondary or tertiary treatment in a municipal wastewater treatment plant or a privately owned wastewater treatment plant.
Do injectate constituents exceed drinking water standards at the point of injection?	Secondary treated effluent may contain fecal coliform and nitrates at concentrations above primary drinking water standards, and either secondary or tertiary treated effluent also may exceed secondary drinking water standards for chloride, sulfate, or total dissolved solids. Available injectate quality data for STE wells show that injectate samples have exceeded drinking water standards for fecal coliform, nitrates, total dissolved solids, and pesticides at at least one facility. Also, available information indicates that at least one facility is permitted to discharge injectate that exceeds the secondary drinking water standard for chloride.
What are the characteristics of the injection zone of a STE well?	Some STE wells inject into shallow (<50 feet) aquifers that are of extremely poor quality and that are not likely to be used as sources of drinking water. However, other wells are used to inject treated wastewater effluent for aquifer recharge, and may be injecting into aquifers of drinking water quality.
Are there any contamination incidents associated with STE wells?	Several studies and incidents have shown that STE wells may have contributed to or caused ground water or surface water contamination. One study showed nitrate contamination of onsite ground water at a STE site in NH where both primary treated effluent and raw septage were released into a leach field. Two STE wells on the Island of Maui, HI were thought to be causing surface water contamination through migration of nitrates in the injectate to surface water bodies.
Are STE wells vulnerable to spills or illicit discharges?	STE wells are not vulnerable to spills or illicit discharges. The injectate is treated wastewater, and the wastewater treatment plants that generate the injectate are generally subject to effluent quality standards and monitoring, reporting, and record keeping requirements.
How many STE wells exist in the United States?	There are 1,675 documented sewage treatment wells and more than 1,739 wells estimated to exist in the United States.
Where are STE wells located within the United States?	More than 95 percent of the documented wells are located in five states: AZ (79); CA (205); FL (830); HI (378); and MA (105). NY did not report any documented STE wells in the state, but reported that less than 50 wells may actually exist.
How are STE wells regulated in states with the largest number of this type of well?	*Permit by rule*: ID, TX *Aquifer Protection Program Permit*: AZ *Ground Water Discharge Permit*: MA, NH, and WI (for discharge into a shallow subsurface absorption field located in the unsaturated zone above the water table). *Individual permit*: CA, FL, HI, WV, OR, WY *Banned*: WI (for direct discharge from a sewage treatment plant into a saturated formation)
Where can I obtain additional information on STE wells?	For general information, contact the Safe Drinking Water Hotline, toll-free 800-426-4791. The Safe Drinking Water Hotline is open Monday through Friday, excluding federal holidays, from 9:00 a.m. to 5:30 p.m. Eastern Standard Time. For technical inquiries, contact Amber Moreen, Underground Injection Control Program, Office of Ground Water and Drinking Water (mail code 4606), EPA, 401 M Street, SW, Washington, D.C., 20460. Phone: 202-260-4891. E-mail: moreen.amber@epa.gov. The complete Class V UIC Study (EPA/816-R-99-014, September 1999), which includes a volume addressing STE wells (Volume 7), can be found at http://www.epa.gov/OGWDW/uic/cl5study.html.

Type or print all information. See reverse for instructions.

OMB No. 2040-0042 Approval Expires 4/30/07

INVENTORY OF INJECTION WELLS

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF GROUND WATER AND DRINKING WATER

(This information is collected under the authority of the Safe Drinking Water Act)

1. DATE PREPARED *(Year, Month, Day)*: 08-10-06

2. FACILITY ID NUMBER: Unknown

PAPERWORK REDUCTION ACT NOTICE

The public reporting burden for this collection of information is estimated at about 0.5 hour per response, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding the burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Chief, Information Policy Branch, 2136, U.S. Environmental Protection Agency, 401 M Street, SW, Washington, DC 20460, and to the Office of Management and Budget, Paperwork Reduction Project, Washington, DC 20503.

3. TRANSACTION TYPE *(Please mark one of the following)*

- [ ] Deletion
- [ ] Entry Change
- [x] First Time Entry
- [ ] Replacement

4. FACILITY NAME AND LOCATION

A. NAME *(last, first, and middle initial)*: USIT WATER RECLAMATION FACILITY

B. STREET ADDRESS/ROUTE NUMBER: The Skagit Resort, 5984 N. Darrk Lane

F. CITY/TOWN: Bow

G. STATE: WA

C. LATITUDE

DEG	MIN	SEC
48	33	59.00

D. LONGITUDE

DEG	MIN	SEC
122	20	41.60

H. ZIP CODE: 98232

E. TOWNSHIP/RANGE

TOWNSHIP	RANGE	SECT	1/4 SECT
36 N	4 E	31	NW

I. NUMERIC COUNTY CODE: 057

J. INDIAN LAND *(mark "x")*: [x] Yes [ ] No

5. LEGAL CONTACT:

A. TYPE *(mark "x")*: [x] Owner [ ] Operator

B. NAME *(last, first, and middle initial)*: Hayden, Bob

C. PHONE *(area code and number)*: (360) 724-0168

D. ORGANIZATION: Upper Skagit Indian Tribe

E. STREET/P.O. BOX: 5984 N. Darrk Lane

F. CITY/TOWN: Bow

G. STATE: WA

H. ZIP CODE: 98232

I. OWNERSHIP *(mark "x")*: [x] PRIVATE [ ] PUBLIC [ ] SPECIFY OTHER [ ] STATE [ ] FEDERAL

6. WELL INFORMATION:

A. CLASS AND TYPE		B. NUMBER OF WELLS: COMM	B. NUMBER OF WELLS: NON-COMM	C. TOTAL NUMBER OF WELLS	D. WELL OPERATION STATUS: UC	AC	TA	PA	AN
5	D		2	2	2				
				0					
				0					
				0					
				0					
				0					
				0					

COMMENTS *(Optional)*:

Both wells (#1 and #2) are to be used for injecting treated effluent from the proposed Upper Skagit Indian Tribe Water Reclamation Facility. Hydrogeologic Report (Subsurface Injection Evaluation, prepared by Associated Earth Sciences, Inc.) is attached. Please call if you have any questions.

KEY:

DEG = Degree
MIN = Minute
SEC = Second

SECT = Section
1/4 SECT = Quarter Section

COMM = Commercial
NON-COMM = Non-Commercial

AC = Active
UC = Under Construction
TA = Temporarily Abandoned
PA = Permanently Abandoned and Approved by State
AN = Permanently Abandoned and not Approved by State

SECTION 1. DATE PREPARED: Enter date in order of year, month, and day.

SECTION 2. FACILITY ID NUMBER: In the first two spaces, insert the appropriate U.S. Postal Service State Code. In the third space, insert one of the following one letter alphabetic identifiers:

D - DUNS Number,
G - GSA Number, or
S - State Facility Number.

In the remaining spaces, insert the appropriate nine digit DUNS, GSA, or State Facility Number. For example, A Federal facility (GSA - 123456789) located in Virginia would be entered as : VAG123456789.

SECTION 3. TRANSACTION TYPE: Place an "x" in the applicable box. See below for further instructions.

Deletion. Fill in the Facility ID Number.
First Time Entry. Fill in all the appropriate information.
Entry Change. Fill in the Facility ID Number and the information that has changed.
Replacement.

SECTION 4. FACILITY NAME AND LOCATION:

- **A. Name.** Fill in the facility's official or legal name.
- **B. Street Address.** Self Explanatory.
- **C. Latitude.** Enter the facility's latitude (all latitudes assume North Except for American Samoa).
- **D. Longitude.** Enter the facility's longitude (all longitudes assume West except Guam).
- **E. Township/Range.** Fill in the complete township and range. The first 3 spaces are numerical and the fourth is a letter (N,S,E,W) specifying a compass direction. A township is North or South of the baseline, and a range is East or West of the principal meridian (e.g., 132N, 343W).
- **F. City/Town.** Self Explanatory.
- **G. State.** Insert the U.S. Postal Service State abbreviation.
- **H. Zip Code.** Insert the five digit zip code plus any extension.

SECTION 4. FACILITY NAME & LOCATION (CONT'D.):

- **I. Numeric County Code.** Insert the numeric county code from the Federal Information Processing Standards Publication (FIPS Pub 6-1) June 15, 1970, U.S. Department of Commerce, National Bureau of Standards. For Alaska, use the Census Division Code developed by the U.S. Census Bureau.
- **J. Indian Land.** Mark an "x" in the appropriate box (Yes or No) to indicate if the facility is located on Indian land.

SECTION 5. LEGAL CONTACT:

- **A. Type.** Mark an "x" in the appropriate box to indicate the type of legal contact (Owner or Operator). For wells operated by lease, the operator is the legal contact.
- **B. Name.** Self Explanatory.
- **C. Phone.** Self Explanatory.
- **D. Organization.** If the legal contact is an individual, give the name of the business organization to expedite mail distribution.
- **E. Street/P.O. Box.** Self Explanatory.
- **F. City/Town.** Self Explanatory.
- **G. State.** Insert the U.S. Postal Service State abbreviation.
- **H. Zip Code.** Insert the five digit zip code plus any extension.
- **I. Ownership.** Place an "x" in the appropriate box to indicate ownership status.

SECTION 6. WELL INFORMATION:

- **A. Class and Type.** Fill in the Class and Type of injection wells located at the listed facility. Use the most pertinent code (specified below) to accurately describe each type of injection well. For example, 2R for a Class II Enhanced Recovery Well, or 3M for a Class III Solution Mining Well, etc.
- **B. Number of Commercial and Non-Commercial Wells.** Enter the total number of commercial and non-commercial wells for each Class/Type, as applicable.
- **C. Total Number of Wells.** Enter the total number of injection wells for each specified Class/Type.
- **D. Well Operation Status.** Enter the number of wells for each Class/Type under each operation status (see key on other side).

CLASS I Industrial, Municipal, and Radioactive Waste Disposal Wells used to inject waste below the lowermost Underground Source of Drinking Water (USDW).

TYPE
- **1I** Non-Hazardous Industrial Disposal Well.
- **1M** Non-Hazardous Municipal Disposal Well.
- **1H** Hazardous Waste Disposal Well injecting below the lowermost USDW.
- **1R** Radioactive Waste Disposal Well.
- **1X** Other Class I Wells.

CLASS II Oil and Gas Production and Storage Related Injection Wells.

TYPE
- **2A** Annular Disposal Well.
- **2D** Produced Fluid Disposal Well.
- **2H** Hydrocarbon Storage Well.
- **2R** Enhanced Recovery Well.
- **2X** Other Class II Wells.

CLASS III Special Process Injection Wells.

TYPE
- **3G** *In Situ* Gassification Well
- **3M** Solution Mining Well.

CLASS III (CONT'D.)

TYPE
- **3S** Sulfur Mining Well by Frasch Process.
- **3T** Geothermal Well.
- **3U** Uranium Mining Well.
- **3X** Other Class III Wells.

CLASS IV Wells that inject hazardous waste into/above USDWs.

TYPE
- **4H** Hazardous Facility Injection Well.
- **4R** Remediation Well at RCRA or CERCLA site.

CLASS V Any Underground Injection Well not included in Classes I through IV.

TYPE
- **5A** Industrial Well.
- **5B** Beneficial Use Well.
- **5C** Fluid Return Well.
- **5D** Sewage Treatment Effluent Well.
- **5E** Cesspools (non-domestic).
- **5F** Septic Systems.
- **5G** Experimental Technology Well.
- **5H** Drainage Well.
- **5I** Mine Backfill Well.
- **5J** Waste Discharge Well.

APPENDIX B

APPENDIX B
UPPER SKAGIT INDIAN TRIBE
RAW SEWAGE SAMPLING DATA

Avocet Environmental Testing
1500 North State Street, Suite 200
Bellingham, WA 98225
(360) 734-9033

AVOCET ENVIRONMENTAL TESTING

Client	**Samish Water District**
Contact Name	Ken Vogel
Chain of Custody	3453
Date Sampled	10/17/07
Date Received	10/17/07
Date Reported	10/31/07
Matrix	Waste Water

Sample I. D.	Log No.	Test Performed	Method	Sample Result	Units	PQL	Date Analyzed	Analyst
~~Dark~~ Lane M.H. Darrk (Upper Skagit Tribe Flows)	05758940	Nitrate	300.0	**<0.05**	mg/L	0.05	10/18/07	EB
		Nitrite	300.0	**<0.05**	mg/L	0.05	10/18/07	EB
		Ortho-Phosphate	300.0	**8.4**	mg/L	1.0	10/18/07	EB
		T. Phosphorus	365.1	**12**	mg/L	0.10	10/29/07	JK
		TKN	351.2	**50**	mg/L	1.0	10/29/07	JK
		TSS	2540D	**330**	mg/L	33	10/19/07	JK
		BOD	5210B	**450**	mg/L	200	10/17/07	JK
		Hardness	2340C	**30**	mg/L	1.0	10/19/07	JK
		Antimony	3113B	**<0.005**	mg/L	0.005	10/23/07	ML
		Arsenic	3113B	**<0.002**	mg/L	0.002	10/24/07	ML
		Barium	3113B	**3.5**	mg/L	0.02	10/30/07	ML
		Beryllium	3113B	**<0.002**	mg/L	0.002	10/29/07	ML
		Cadmium	3113B	**<0.0005**	mg/L	0.0005	10/23/07	ML
		Chromium	200.8/3010A	**0.002**	mg/L	0.001	10/29/07	*
		Hexavalent Chromium	sm3500-CrD	**ND**	mg/L	0.010	10/17/07	*
		Copper	3113B	**0.047**	mg/L	0.005	10/22/07	ML
		Iron	3111B	**0.74**	mg/L	0.1	10/25/07	ML
		Lead	3113B	**0.001**	mg/L	0.001	10/22/07	ML
		Mercury	245.1	**<0.0005**	mg/L	0.0005	10/24/07	ML
		Nickel	3113B	**<0.01**	mg/L	0.01	10/29/07	ML
		Selenium	3113B	**<0.005**	mg/L	0.005	10/31/07	ML
		Silver	3113B	**<0.002**	mg/L	0.002	10/23/07	ML
		Thallium	200.9	**<0.001**	mg/L	0.001	10/29/07	ML
		Zinc	3111B	**0.19**	mg/L	0.025	10/22/07	ML

Laboratory Supervisor

MONTHLY TSS AND BOD TOTALS

March, 06 **USIT**

DATE	TSS mg/ L	BOD mg/L
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15	272	447
16	388	
17	400	
18		
19		
20		
21	448	
22	356	612
23	360	
24	516	
25		
26		
27		
28	300	
29	296	
30	332	
31	388	
	TOTALS	
	4056	1059
	AVERAGE	
	369	530

MONTHLY TSS AND BOD TOTALS

April 06 **USIT**

DATE	TSS mg/ L	BOD mg/L
1		
2		
3		
4	716	
5	556	702
6	1388	
7	788	
8		
9		
10		
11	852	
12	528	1017
13	832	
14	676	
15		
16		
17		
18	472	
19	544	780
20	556	
21	468	
22		
23		
24		
25	1672	
26	316	
27	2760	
28	548	
29		
30		
31		
	TOTALS	
	13672	2499
	AVERAGE	
	855	833

MONTHLY TSS AND BOD TOTALS

May, 06 **USIT**

DATE	TSS mg/ L	BOD mg/L
1		
2	500	
3	1776	576
4	536	
5	804	
6		
7		
8		
9	678	
10	440	594
11	248	
12	500	
13		
14		
15		
16	316	
17	240	432
18	212	
19	544	
20		
21		
22		
23	784	
24	332	495
25	336	
26		
27		
28		
29		
30	272	456
31		
	TOTALS	
	8518	2553
	AVERAGE	
	532	511

MONTHLY TSS AND BOD TOTALS

June, 06 **USIT**

DATE	TSS mg/ L	BOD mg/L
1	288	
2	408	
3		
4		
5		
6	372	
7	452	471
8	324	
9	1376	
10		
11		
12		
13	2200	
14	320	470
15	340	
16	436	
17		
18		
19		
20	688	
21	364	203
22	440	
23	476	
24		
25		
26		
27	464	
28	360	597
29	304	
30		
31		
	TOTALS	
	9612	1741
	AVERAGE	
	565	435

MONTHLY TSS AND BOD TOTALS

July, 2006 **CASINO**

DATE	TSS mg/ L	BOD mg/L
1		
2		
3		
4		
5	590	495
6	400	
7	320	
8		
9		
10		
11	284	
12	384	657
13	424	
14	556	
15		
16		
17		
18	388	
19	276	372
20	260	
21	208	
22		
23		
24		
25	No sample	
26	360	429
27	560	
28	300	
29		
30		
31		
	TOTALS	
	5310	1953
	AVERAGE	
	379	488

MONTHLY TSS AND BOD TOTALS

August 2006
~~October, 05~~ **USIT**

DATE	TSS mg/ L	BOD mg/L
1	572	
2	540	473
3	352	
4		
5		
6		
7		
8	444	
9	268	300
10	276	
11	312	
12		
13		
14		
15	308	
16	344	353
17	320	
18	268	
19		
20		
21		
22	364	
23	360	327
24	244	
25	280	
26		
27		
28		
29		
30	292	567
31		d
	TOTALS	
	5544	2020
	AVERAGE	
	347	404

MONTHLY TSS AND BOD TOTALS

September, 2006 **USIT**

DATE	TSS mg/ L	BOD mg/L
1		
2		
3		
4		
5		
6	392	393
7		
8		
9		
10		
11		
12		
13	280	453
14		
15		
16		
17		
18		
19		
20	304	477
21		
22		
23		
24		
25		
26		
27	316	362
28		
29		
30		
31		
	TOTALS	
	1292	1685
	AVERAGE	
	323	421

MONTHLY TSS AND BOD TOTALS

October, ~~05~~ 2006 **USIT**

DATE	TSS mg/ L	BOD mg/L
1		
2		
3		
4	568	250
5		
6		
7		
8		
9		
10		
11	1388	707
12		
13		
14		
15		
16		
17		
18	888	809
19		
20		
21		
22		
23		
24		
25	864	807
26		
27		
28		
29		
30		
31		
	TOTALS	
	3708	2573
	AVERAGE	
	927	643

MONTHLY TSS AND BOD TOTALS

November, 06 **USIT**

DATE	TSS mg/ L	BOD mg/L
1	464	708
2		
3		
4		
5		
6		
7		
8	600	437
9		
10		
11		
12		
13		
14		
15		
16	572	1190
17		
18		
19		
20		
21		
22	396	537
23		
24		
25		
26		
27		
28		
29		
30		
31		
	TOTALS	
	2032	2872
	AVERAGE	
	508	718

MONTHLY TSS AND BOD TOTALS

December 06, **USIT**

DATE	TSS mg/ L	BOD mg/L
1		
2		
3		
4		
5		
6	548	639
7		
8		
9		
10		
11		
12		
13	572	624
14		
15		
16		
17		
18		
19		
20	440	398
21		
22		
23		
24		
25		
26		
27		
28	456	774
29		
30		
31		
	TOTALS	
	2016	2435
	AVERAGE	
	504	609

MONTHLY TSS AND BOD TOTALS

January, 2007

USIT

DATE	TSS mg/ L	BOD mg/L
1		
2		
3	316	606
4		
5		
6		
7		
8		
9		
10	480	498
11		
12		
13		
14		
15		
16		
17	288	516
18		
19		
20		
21		
22		
23		
24	352	530
25		
26		
27		
28		
29		
30		
31	452	699
	TOTALS	
	1888	2849
	AVERAGE	
	378	570

d

MONTHLY TSS AND BOD TOTALS

Feb., 07 **USIT**

DATE	TSS mg/ L	BOD mg/L
1		
2		
3		
4		
5		
6		
7	228	425
8		
9		
10		
11		
12		
13		
14	228	
15		
16		
17		
18		
19		
20		
21	336	668
22		
23		
24		
25		
26		
27		
28	220	554
29		
30		
31		
	TOTALS	
	1012	1647
	AVERAGE	
	253	549

e

MONTHLY TSS AND BOD TOTALS

March 2007 **USIT**

DATE	TSS mg/ L	BOD mg/L
1		
2		
3		
4		
5		
6		
7	324	No sample
8		
9		
10		
11		
12		
13		
14	424	423
15		
16		
17		
18		
19		
20		
21	628	644
22		
23		
24		
25		
26		
27		
28	336	468
29		
30		
31		
	TOTALS	
	1712	1535
	AVERAGE	
	428	512

MONTHLY TSS AND BOD TOTALS

April 2007 **USIT**

DATE	TSS mg/ L	BOD mg/L
1		
2		
3		
4	364	531
5		
6		
7		
8		
9		
10		
11	824	326
12		
13		
14		
15		
16		
17		
18	432	468
19		
20		
21		
22		
23		
24		
25	588	648
26		
27		
28		
29		
30		
31		
	TOTALS	
	2208	1973
	AVERAGE	
	552	493

MONTHLY TSS AND BOD TOTALS

May 2007 **USIT**

DATE	TSS mg/ L	BOD mg/L
1		
2	412	744
3		
4		
5		
6		
7		
8		
9	292	405
10		
11		
12		
13		
14		
15		
16	336	576
17		
18		
19		
20		
21		
22		
23	324	426
24		
25		
26		
27		
28		
29		
30	320	548
31		d
	TOTALS	
	1684	2699
	AVERAGE	
	337	540

MONTHLY TSS AND BOD TOTALS

June, 2007 **USIT**

DATE	TSS mg/ L	BOD mg/L
1		
2		
3		
4		
5		
6	300	579
7		
8		
9		
10		
11		
12		
13	276	503
14		
15		
16		
17		
18		
19		
20		
21	376	633
22		
23		
24		
25		
26		
27	266	431
28		
29		
30		
31		
	TOTALS	
	1218	2146
	AVERAGE	
	305	537

MONTHLY TSS AND BOD TOTALS

July, 2007 **CASINO**

DATE	TSS mg/ L	BOD mg/L
1		
2		
3	428	555
4		
5		
6		
7		
8		
9		
10		
11	308	714
12		
13		
14		
15		
16		
17		
18	328	774
19		
20		
21		
22		
23		
24		
25	324	608
26		
27		
28		
29		
30		
31		
	TOTALS	
	1388	2651
	AVERAGE	
	347	663

MONTHLY TSS AND BOD TOTALS

August 2007 **CASINO**

DATE	TSS mg/ L	BOD mg/L
1	468	399
2		
3		
4		
5		
6		
7		
8	400	429
9		
10		
11		
12		
13		
14		
15	568	540
16		
17		
18		
19		
20		
21		
22	536	593
23		
24		
25		
26		
27		
28		
29	456	690
30		
31		
	TOTALS	
	2428	2651
	AVERAGE	
	486	530

MONTHLY TSS AND BOD TOTALS

September 2007

USIT

DATE	TSS mg/ L	BOD mg/L
1		
2		
3		
4		
5	440	501
6		
7		
8		
9		
10		
11		
12	628	519
13		
14		
15		
16		
17		
18		
19	336	369
20		
21		
22		
23		
24		
25		
26	400	396
27		
28		
29		
30		
31		
	TOTALS	
	1804	1785
	AVERAGE	
	451	446

MONTHLY TSS AND BOD TOTALS

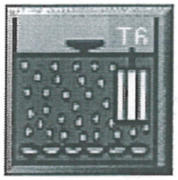
October, 07 **USIT**

DATE	TSS mg/ L	BOD mg/L
1		
2		
3	388	488
4		
5		
6		
7		
8		
9		
10	368	378
11		
12		
13		
14		
15		
16		
17	440	422
18		
19		
20		
21		
22		
23		
24	400	1222
25		
26		
27		
28		
29		
30		
31	296	623
	TOTALS	
	1892	3133
	AVERAGE	
	378	627

d

APPENDIX C

APPENDIX C
DOE CRITERIA FOR SEWAGE WORKS DESIGN
CHAPTER T6 – MEMBRANE BIOREACTOR TREATMENT SYSTEMS



T6 Membrane Bioreactor Treatment Systems

(New chapter 10/2006)

This chapter provides an overview of membrane bioreactor (MBR) treatment systems. It describes typical facility design considerations including process configuration, biological treatment components, and membrane design factors.

Figures

Tables

T6-1 Objective

Membrane bioreactor (MBR) treatment systems have gained acceptance as a viable alternative for municipal wastewater treatment. With advances in membrane technology and increased manufacturer competition and experience, there is an increased potential for MBR treatment systems to be an effective technical option and a cost effective alternative treatment option for communities. This chapter will provide engineers, wastewater officials, and operators with a common understanding of the key factors influencing the design of MBR treatment systems.

Ecology obtained the information presented in this chapter from *Water Environment Federation's Membrane Systems for Wastewater Treatment* (WEF Press/McGraw-Hill 2006) as well as from other references listed at the end of this chapter. Ecology based the design values presented in this chapter on the best information available at the time of this writing. These values may change as this technology continues to develop. Ecology intends that inclusion of design values is for general reference only and should not be considered as absolute target values. Requirements for each proposed MBR project will be specific to the local conditions, influent characteristics, system size, membrane type chosen, the complete treatment train configuration, the target effluent quality and other criteria. Designers must present justification of all design values used in a treatment plant design based on site-specific characteristics.

T6-2 Background

Development of membrane bioreactor wastewater treatment dates to the mid-1960's with the emergence of systems using external, tubular, pressure-driven microfiltration membranes in combination with aerobic biological treatment to treat high strength or difficult to treat wastewaters. In the early 1990s, submerged or immersed, vacuum-driven microfiltration and ultrafiltration membranes were developed and applied in membrane bioreactors, greatly reducing the energy requirements for MBRs, while maintaining the advantages of the previous pressure-driven systems. With further improvements in membrane manufacturing techniques, decreases in energy consumption, and increasing regulatory pressure for advanced wastewater treatment, MBR technology has found greater application. This chapter will provide a review of current general design practices for wastewater treatment facilities proposing to use MBR technology.

The latest MBR systems combine activated sludge biological treatment with submerged membrane filtration for solids separation. Membranes used in MBRs are generally categorized as low-pressure microfiltration or ultrafiltration membranes. The nominal pore sizes for MF/UF membranes currently used in MBR applications range between 0.01-0.4 μm.

T6-2.1 Application

MBR systems are well suited for treatment applications needing high quality effluent and/or where available space is limited. General benefits include:

- Exceptional effluent quality (BOD_5 and TSS < 5mg/L, turbidity <0.1 NTU).
- Small footprint with the potential for modular construction.
- Reliable operation.
- Reduced downstream disinfection requirements.
- More robust nitrification/denitrification process due to the relatively high liquor concentration.

High effluent quality and stable operation of MBR systems also make them appealing for water reclamation projects (further information on water reclamation projects can be found in Chapter E1).

Potential drawbacks of MBR systems include:

- Membranes physically limit a plant's ability to accommodate high peaking factors, which will require the proponent to develop strategies to ensure treatment of excess flow.
- Limited amount of long-term system reliability data.
- Systems are manufacturer specific, which present challenges for system comparison and design efficiency.
- Higher capital and operation and maintenance costs when compared to conventional activated sludge (CAS) processes designed to meet standard secondary treatment requirements. (*Note: MBR processes can be cost effective when comparing with secondary and tertiary treatment systems designed to meet high quality effluent requirements to meet strict water quality standards or water reuse standards*)
- Reliance on air scouring of membranes results in higher energy consumption compared to CAS facilities.
- Increased potential for foam due to preferred operating conditions.
- Strict operations and maintenance requirements to prevent membrane fouling and failure.

T6-2.2 Performance

Under proper conditions, systems can reliably reduce turbidity to less than 0.1 NTU, BOD_5 to less than 2 mg/L, ammonia-nitrogen to less than 1mg/L and can provide a 4-6 log removal of fecal coliform bacteria. Engineers and wastewater treatment plant operators can expect MBR installations to achieve the following concentrations of conventional pollutants and nutrients in MBR treated effluents:

Table T6-1 Expected MBR Treated Effluent Characteristics

Parameter	Units	Typical Value
$CBOD_5$	mg/L	<5
TSS	mg/L	<1
Ammonia	mg/L as N	<1
Total Nitrogen (with pre-anoxic zone)	mg/L	<10
Total Nitrogen (with pre-anoxic and post-anoxic zones)	mg/L	<3
Total Phosphorus (with chemical addition)	mg/L	<0.2 (typical) <0.05 (achievable)
Total Phosphorus (with Bio-P removal)	mg/L	<0.5
Turbidity	NTU	<0.2
Bacteria	log removal	up to 6 log (99.9999%)

From *Membrane Systems for Wastewater Treatment*, Water Environment Federation, WEF Press/McGraw-Hill, 2005

T6-3 General Process Overview

T6-3.1 General process theory

MBR systems essentially combine conventional biological wastewater treatment with membrane filtration. Unlike CAS processes, MBR processes require upstream fine screening to remove potentially damaging solids from the influent sewage and, typically, they operate at substantially higher mixed liquor concentrations. Soluble organic matter, some particulate organics, nutrients (based on configuration) and some metals are removed through biological processes within the aeration basin, similar to CAS processes. MBR processes, however, separate solids through membrane filtration rather than by sedimentation in secondary clarifiers. As with CAS, the biological treatment configuration of MBR facilities depends on the degree of nutrient removal required for the facility. MBR systems can incorporate anoxic and/or anaerobic basins for nutrient removal (nitrogen and phosphorus) into the designs.

T6-3.2 Typical process configuration

MBR-based treatment facilities can include fine screening, grit removal, oil/grease separators (for systems with problems with influent fats, oils and grease), activated sludge biological treatment, submerged membrane filtration, and disinfection.

As a space saving measure, early MBR system designs located the membranes within the aeration basins. Although this design philosophy may continue to be used, especially in small-scale package installations, the current trend locates the membranes in separate tanks that the operator can more easily take membranes out of service. Market pressures have encouraged this practice to allow for membranes to be cleaned and maintained with minimal need to remove them from the basin.

Designs may also incorporate anoxic and/or anaerobic regions in baffled zones or separate tanks. MBR system manufacturers commonly incorporate anoxic zone requirements primarily to conserve alkalinity and secondarily to enhance nitrogen removal. MBR system manufacturers often use nitrification as a surrogate to demonstrate complete oxidation of soluble BOD, which has been identified as a contributor to membrane microbial fouling. Anoxic and anaerobic regions may also serve as a biological nutrient (nitrogen and phosphorus) removal (BNR) strategy. Additional information on BNR in activated sludge processes can be found in section T.3-3.2.

T6-3.3 General types of membranes

Although a number of MBR system manufacturers have emerged in recent years, available immersed systems generally consist of one of two basic membrane shape types:

- **Hollow Fiber:** Hollow fiber systems are composed of bundles of fine membrane fibers (approximately 0.5-2 mm diameter range) that are arranged and supported on a stainless steel frame. The outer surface of each fiber is exposed to the mixed liquor; filtrate flows from outside to inside through membrane pores by applying a vacuum or creating a siphon on the inside of the membranes. Depending on manufacturer-specific configurations, the effective membrane surface area of each module ranges between 250-600 ft^2.

- **Flat Plate:** Flat plate systems arrange membranes in rectangular cartridges with a porous backing material sandwiched between two membranes for structural support. Individual cartridges are arranged into stainless steel racks designed to house 25 to 200 cartridges with effective surface areas between 8.5-13.5 ft^2 per cartridge.

T6-4 Facility Design

T6-4.1 Pretreatment

Pretreatment is critical in MBR plant design to ensure adequate protection of membranes from physical damage. All systems require fine screening and grit removal to prevent membrane damage from abrasive particles common in influent sewage. Removal of fibrous or stringy material is also important. This material can become entangled and wrap around the hollow fibers or stuck within the gaps between membrane flat plates. This can plug the membrane scour aeration systems leading to problems with operation of and potential damage to the system. If historic problems with fats, oils and grease (FOG) exist within the community, oil and grease removal may also be necessary to prevent membranes from being coated.

Early installations were designed with fine screens in the 3-6 mm range. With increased operational experience, manufacturers have decreased the preferred screening size to limit overall operation and maintenance concerns. Independent evaluation of various MBR systems has shown that 1-2 mm screens appear to be optimal for MBR performance without greatly increasing the required operation and maintenance of the pretreatment headworks. There is also added protection of the biological equipment in the system with the improved pretreatment. Large-scale facilities should consider dual screen installations with coarse (6-9 mm) screens followed by fine screens. This configuration provides sufficient screening while minimizing complications inherent in managing fine screening (high flow restrictions and increased solid waste handling). Designers must consult the MBR manufacturer's for screening recommendations.

Fine screening requirements for MBR applications require designers to pay special attention to headworks design criteria. Due to increased flow resistance and solids collection, headworks designs with fine screens require modification away from traditional designs with coarse screens. Fine screens must be:

- Inclined 60 to 80 degrees from the channel floor (in contrast to 90 degrees for many coarse screens) with a minimum of 2 screens per installation.
- Limited to a channel depth of 25 feet or less to minimize equipment cost,
- Able to accommodate an additional 1 to 2 feet of head loss versus traditional coarse screens (Keller 2005).

Due to the increased presence of fecal material in fine screenings, washing and compaction equipment are recommended. Fine screens can be expected to remove approximately 0.33 cubic yards of waste solids per million gallons of flow per day. Additional information on fine screening can be found in Chapter T1.

In addition to fine screening, engineers should consider inclusion of primary clarifiers in MBR plant designs. Use of primary clarification in large-scale systems will generally lead to the following benefits:

- Reduction in down-stream MBR treatment component sizes
- Some flow equalization capacity
- A redundant layer of protection from small grit particles

Proposals that do not include primary clarification must justify why primary clarifiers are not practical due to facility size constraints or limited benefit in comparison to the cost of handling primary solids. Engineers are more likely to design small-scale, package installations without primary clarification.

T6-4.2 Biological Treatment Component

Biological treatment within an MBR facility is analogous to conventional activated sludge treatment with some major differences. These differences are discussed in detail below.

T6-4.2.1 Design range for mixed liquor concentrations/sludge age

MBR systems operate at increased mixed liquor suspended solids (MLSS) concentrations and longer sludge ages, thereby minimizing reactor volumes and waste sludge handling requirements. Historically, MBR designs specified very high MLSS concentrations of 15,000 mg/L to 30,000 mg/L and sludge ages between 30-70 days. Current practice has reduced both values in consideration of aeration requirements and membrane performance. Hollow fiber manufacturers typically specify MLSS concentrations between 8,000-15,000 mg/L based on a need to ensure aeration efficiency. Flat plate manufacturers often specify MLSS concentrations between 8,000-20,000 mg/L based on a desire to form a biofilm/biosolids layer on the surface to aid in treatment and filtration.

Depending on treatment goals, recommended sludge age for both types of systems range between 10-60 days. The currently recommended combinations of solids concentrations and sludge age provide sufficient biological treatment activity while considering aeration, flux rates, and cleaning frequency. A long Solids Retention Time (SRT) allows slower growing microbial populations, such as nitrifiers, the opportunity to establish viable populations. A diverse consortium of microbes allows for increased resistance to toxic upsets and better degradation of complex organics.

T6-4.2.2 Aeration requirements

As with any biological treatment system, aeration maintains biomass stability. Engineers should base aeration system designs for MBR applications on criteria similar to conventional activated sludge (see Chapter T3 for conventional activated sludge design). The exceptions, however, are that oxygen transfer efficiencies in MBR systems will be lower due to higher MLSS concentrations. Further, shallow depths and use of coarse bubble diffusers in membrane basins will also affect the performance of this part of the system. Engineers must design to ensure sufficient aeration will be available at all times.

Operational planning for proposed MBR systems must ensure the system can supply air sufficient to meet biological needs. The combination of high design MLSS concentrations and small tank volumes makes it possible for biological oxygen requirements to exceed volumetric air capacity. Engineers must balance tank volumes and aeration capacity with the elevated oxygen uptake rates (OUR) typically seen in MBR applications. Designers must justify that:

- The predicted OUR for a proposed project is reasonable and achievable with the selected aeration system.
- The tank volume-aeration system design balance will serve the system's needs.
- The aeration system incorporates sufficient turndown to handle changing process conditions

Research in this area is ongoing, and the available information is insufficient to form meaningful design guidance. Ecology will revise this document as more data on appropriate oxygen uptake rates become available.

High MLSS concentrations typical in MBR systems greatly affect oxygen transfer within aeration basins. The decreased transfer rate within the activated sludge matrix can be attributed to increased bubble coalescence due to the high viscosity of the fluid along with increased production of extracellular polymeric substances (EPS) (Krampe 2003). Increasing MLSS concentrations and mixed liquor viscosity result in decreases in α-values. An evaluation of two full-scale municipal MBR plants in Germany determined an average α-value of 0.6 ± 0.1 when the plants operated at 12,000 mg/L MLSS. The authors reported an α-value of 0.8 for conventional activated sludge plants operating at 3,000-5,000 mg/L MLSS (Cornel 2003). Krampe's study on oxygen transfer in concentrated MLSS suggests the following equation to estimate α-values based on observed performance in MBR applications using fine bubble diffusers:

$$\alpha = e^{-0.08788 * MLSS}$$

where MLSS is expressed in g/L

This equation predicts much lower α-values than values suggested by Cornel. Given the disparity of observed values, the designer must provide a clear rationale to support the choice of α-value used for a proposed project. At no time will Ecology accept the application of an α-value for a conventional activated sludge process to an MBR design because this will under-predict air needs.

As with CAS systems, diffuser choice affects oxygen transfer efficiency. With MBRs, the need for aeration and membrane scouring often leads to conflicting diffuser requirements. Fine bubble diffusers supply the best oxygen transfer efficiency with respect to applied blower energy, while course bubble diffusers are required to provide sufficient scouring energy and are normally included in the membrane system. The air volume required to clean the membrane surface is independent of the aeration requirements and can not be adjusted for various influent loadings. A common compromise of the competing needs for efficient oxygen transfer and scour energy is to use a combination of coarse bubble diffusers supplied with the membranes and controlling any additional aeration requirements with separate fine bubble diffusers. In systems designed with separate aeration and membrane tanks, engineers typically design fine bubble diffusers in the aeration tank and coarse bubble diffusers in the membrane tanks. If the system uses a single tank design, diffusers must be arranged to provide sufficient scouring at the membranes and sufficient aeration in other regions of the tank.

Course bubble diffusers in the MBR provide some aeration capacity, which engineers may consider as part of the overall aeration design. Unlike conventional systems that have little or no dissolved oxygen in the return activated sludge (RAS) from secondary clarifiers, RAS from the membrane tanks contains oxygen levels between 1-6 mg/L. Engineers may use this oxygen credit in the RAS to offset air needs in the aeration tanks. In claiming this credit, designers must provide a reasonable accounting of the oxygen balance within the system and justify that sufficient aeration capacity will exist. This credit can be counted when RAS is directed into the aerobic tank(s) only. In cases where the recycle stream is directed to the anoxic or anaerobic zone, the oxygen credit cannot be counted and designs must incorporate features to remove oxygen from the RAS.

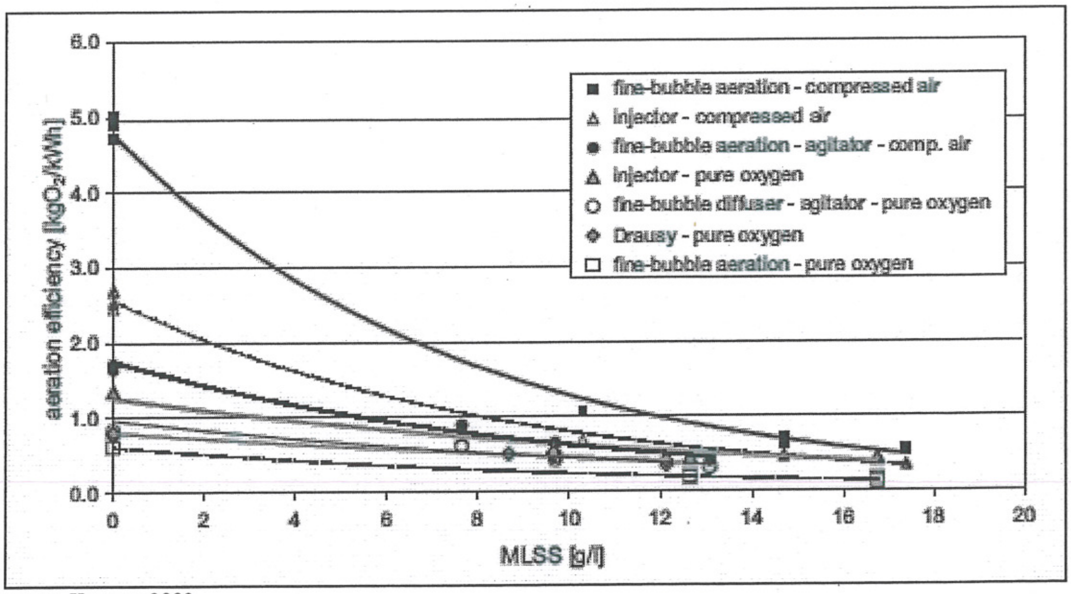
T6-4.2.3 Blower Requirements

Process air requirements for MBR systems are divided into three areas based on end-uses. Aeration of the activated sludge and air scouring within the membrane basin represent the two largest air demands. Clean, dry compressed air, necessary to actuate pneumatic valves and to operate pneumatic pumps, represents the third air requirement.

A. Aeration Blowers

Designers must size blowers to deliver sufficient air to ensure biological activity at design loading and must justify the optimal air needs with biological process modeling. Designers may use either positive displacement or centrifugal blowers for larger systems and regenerative blowers for smaller plants. Designers typically install them as a common group of duty plus standby units. Blowers should discharge to a common header that delivers to individual diffuser grids in the aerobic zones. Installation typically separates aeration blowers from membrane scour blowers.

The higher MLSS concentrations in MBRs decrease the aeration efficiencies of diffusers with respect to applied blower energy. Figure T6-1 shows the declining aeration efficiency for a variety of aeration strategies at MLSS concentrations up to 18,000 mg/L. Designers must account for this decrease in efficiency when sizing aeration blowers. This is generally accomplished in the selection of appropriate α-values.



Source: Krampe 2003

Figure T6-1 Aeration Efficiency versus MLSS

B. Membrane Scour Blowers

MBR systems require separate blowers to supply the air demand for membrane scouring. Air demand for membrane scouring typically ranges between 0.01-0.04 cfm per square foot of membrane within the treatment basin. Operation of this system is slightly different than the aeration blowers as the volume of air required is dependent on the amount of membranes in operation as opposed to biological aeration requirements. Membrane manufacturers specify the actual air flow requirements necessary to provide adequate scouring for each individual cassette or rack in a given installation. Designers must size the system of blowers to provide the air needs for the total number of racks/cassettes installed in a basin. The blower system must provide air at the maximum allowable fluid height of the basin. As with the aeration blowers, designers may use either positive displacement or centrifugal/regenerative type blowers for membrane scour. These blowers are typically installed as a common group of duty plus standby units. Blowers should discharge to a common header. Systems designed for phased expansion should install oversize blowers with flow controlled by variable frequency drives, inlet control vanes or resheaving. This provides flexibility to add membranes for future needs without adding blower capacity. For blowers operating in systems with cyclic air scouring, engineers should design fixed speed blowers with air routing determined by pneumatically operated valves.

T6-4.2.4 Sludge Recycling

As with conventional activated sludge systems, activated sludge recycle maintains system biological activity. With MBR systems, however, recycle from the membrane section also maintains sludge inventory distribution and system sustainability. Without maintaining a minimum recycle rate from the membrane tank/section, the MLSS concentration increases rapidly in the membrane zone and is depleted in the biological zones. This leads to biomass degradation and decreased flux rates due to accumulation of biomass at the membrane surface (referred to as "sludging"). Early system designs typically provided recycle rates between 200 percent and 400 percent of the plant influent flow. Current designs typically specify recycle flows of 300-500 percent of influent flow. Ecology will consider recycle rates within either range as valid when designers provide supporting justification. Peak hour flows must also be considered in any evaluation of recycle requirements along with residual DO concentrations.

Routing of recycle flow within MBR systems can pose unique problems due to very high concentrations of dissolved oxygen (DO) in the membrane basins (1-6 mg/L). Systems configured with anoxic and anaerobic sections require careful routing of recycle streams to prevent excess DO from entering these zones. Designers must identify strategies to limit introduction of DO into anoxic or anaerobic basins. Strategies may include, but are not limited to, use of a de-aeration basin, mixing with the influent, inclusion of a larger anoxic basin, or alternative routing of RAS through the aeration basin.

T6-4.2.5 Activated Sludge Wasting

Activated sludge wasting maintains MLSS concentrations or SRT within a predetermined range. Engineers may design either automated or manually-initiated wasting. Designs may incorporate solids withdrawal from a variety of locations. Designers may choose to waste sludge from either the membrane basin or aeration basin or from both and to withdraw sludge from the recirculation lines, a separate drain line, or from basin surfaces. Design specifications for maximum target MLSS concentrations must identify the location for measurement as concentrations in aeration basins and membrane basins will be significantly different. Due to the removal of treated effluent through the membranes, the membrane basin will always have a proportionally higher MLSS concentration than the biological system. Sludge wasting may be continuous or intermittent, depending on membrane manufacturer preference and site constraints.

T6-4.3 Membrane Design Factors

Individual MBR manufacturers differ with respect to the type of membrane material and initial pore size. Typical effective pore sizes for microfiltration membranes used in MBRs range between 0.1-0.4 microns, while ultrafiltration membranes used in MBRs are in the 0.02 to 0.1 micron range. Flat sheet vendors typically offer pore sizes at the higher end of the microfiltration range, while hollow fiber systems vary across the range. While individual manufacturers use different membrane materials and filtration strategies, the basic design approach for the overall proposed systems is similar, and achievable effluent quality is comparable. The ability for MBR systems to efficiently pass flow influences much of the total system design needs. Membrane flux rate and system flux management are two of the most important parameters for any MBR system design.

T6-4.3.1 Flux rate and design flow rate

Flux rate through the membrane is expressed in gallons per day per square-foot of membrane area (gpd/ft^2, also commonly expressed as gfd). The amount of flow that can pass through the membrane dictates the total surface area and, therefore, overall plant infrastructure necessary to accommodate anticipated influent flow rates. Consideration must be given to the total instantaneous flux of the entire system along with the net flux of the system with some membrane modules off-line for routine maintenance/recovery cleaning (see <u>T6-4.3.3</u> for further discussion on membrane cleaning). To ensure adequate system design, engineers must identify the following anticipated plant flows:

- Maximum monthly flow with corresponding minimum water temperature.
- Peak daily flow with corresponding minimum water temperature; number of consecutive days that this peak day flow can occur, the frequency of the event and the time in between such events.
- Peak hourly flow with corresponding minimum water temperature; number of consecutive hours that this peak hourly flow can occur during typical diurnal profile and during peak daily flow event.
- Peak instantaneous flow with corresponding minimum water temperature; number of consecutive minutes that this peak instantaneous flow can occur in each 24-hr cycle of operation during both average and peak day flow conditions.

The need to provide treatment for the preceding flow rates influences membrane surface area requirements. Membrane manufacturers specify operating flux rates at design minimum water temperatures. Operational flux rates vary depending on temperature, solids concentration, and solids retention time. Designers must specify the operating environment in which stated flux rates are valid. Rates must be compared with predicted operating environments during periods when peak flows will be expected. To ensure adequate design, plans must identify the sustained average daily flux, peak flux rate, and duration and maximum daily flux. Definitions for average and peak flux rates follow:

- Average daily flux is the sustained average daily flow through the membranes. Engineers must design systems to provide sufficient membrane surface area to pass the daily average influent design flow.
- Peak flux rate is the highest flow rate though the membranes that can be sustained for a short period of time (engineers must specify length of peak flow, frequency of occurrence, and time required for the membrane recovery when appropriate). Peak flux rate functions as the limiting factor in the plant's ability to pass the peak hourly influent expected for the facility. Ecology expects facilities to accommodate peak hour design flows through either treatment or flow equalization storage. Depending on the technology, membrane systems can economically treat flows with a peaking factor between 2.0-2.5 greater than the average daily flow. Facilities that expect a peaking factor greater than 2.5 must accommodate higher flows with equalization volume, off-line storage or reserve membrane capacity (excess surface area) if equalization or storage is not available.

Flux rates used in proposed designs vary depending on specific wastewater characteristics and membrane design and require justification on a case-by-case basis. Typical MBR flux rates found in literature suggest a reasonable promoted more EPS production (Ng 2006). System designs should include methods for controlling biofouling by decreasing EPS (Frechen 2005).

While research continues to provide an understanding of the factors involved in EPS production and biofouling, designers continue to test operational strategies for controlling biofouling. General strategies include close monitoring of the biological processes to ensure a healthy, stable environment for the biomass. Important monitoring parameters include F/M ratio, carbon-nitrogen ratio, and SRT. Manufacturers have identified coagulant use as a potential means to reduce biofouling by agglomerating free EPS. Design proposals need to assess the potential for biofouling on a case-by-case basis and must identify appropriate control strategies. As this area of MBR design evolves, alternative control measures are acceptable.

T6-4.3.3 Membrane Cleaning

Operators may restore membrane permeability in several ways. Air scouring, which is used by all MBR system designs, aids in maintaining permeability by disrupting the cake of biosolids that builds up at the membrane surface. However scouring does not reverse the decrease in permeability due to fouling (biological or chemical). Designers may consider the following on-line and off-line strategies to improve operational permeability during design. The proponent must identify and justify an appropriate combination of cleaning strategies to be used on a case-by-case basis. Designers may also consider alternative strategies not listed here.

A. Relax

Permeate flow for a membrane train is suspended and the air scour is left on, typically in cycles of 30 seconds to 1 minute out of every 10 to 15 minutes. Reducing the forces associated with permeate forward flow allows small particles that are loosely bound to the surface to slough. All MBR designs include this method of operation.

B. Backpulse/Backwash

Reversal of permeate flow through the membranes flushes particles from membrane pores and cavities. This strategy, which can be used with relax or as an alternative to the relax strategy, applies primarily to hollow fiber systems. Flat plate manufacturers do not generally adopt this cleaning method because the construction of the plates does not allow for adequate backflow pressure without damaging the cassettes. Some hollow fiber suppliers are moving away from this method because it can derate plant capacity and may damage membranes over time.

C. Chemical Backwash/Maintenance Cleaning

Backwashing membranes with permeate containing low concentrations of hypochlorite or citric acid aids in removing some of the organic and inorganic buildup that the above cleaning methods alone will not address. This option attempts to prevent the build up of fouling compounds and reduce the potential for irreversible fouling. This strategy applies only to hollow fiber systems as it requires the membrane to be capable of allowing backpressure. Operators typically perform maintenance cleaning on a semi-weekly to weekly frequency, depending on manufacture requirements and wastewater constituents.

D. **Recovery Cleaning**

Recovery cleaning requires individual membrane units to be taken off-line for more intense chemical cleaning. During recovery cleaning of flat plate systems, the operator will fill individual membrane cartridges with cleaning chemicals (hypochlorite, oxalic acid, or hydrochloric acid) and will allow them to soak for 6-24 hours. This deep cleaning can restore permeability to approximately 80 percent of the permeability observed after the initial break-in period. For hollow fiber systems with backpulse included in the design, chemicals (sodium hypochlorite or citric acid solutions) are generally automatically introduced to an entire membrane unit when initiated by the operator. Without automated cleaning, the membrane unit basin is generally drained and filled with a chemical solution to soak the membrane unit or a membrane cartridge is moved to a cleaning solution basin. These systems are allowed to soak for 6-24 hours. Depending on wastewater characteristics and/or manufacture preferences, operators should schedule recovery cleaning on 3-month to 1-year frequencies. During cleaning, wastewater flow needs to be routed to other treatment trains or stored in equalization basins. Designs can provide for recovery cleaning within an isolated section of the membrane basin or with membrane removal to a dedicated recovery cleaning tank. Designers must address disposal of cleaning chemicals for systems designed to clean in the membrane tank because the chemicals may disturb biological processes.

T6-4.4 Overall Design Considerations

Tank requirements differ between membrane designs and MBR systems. Early identification of the preferred MBR manufacturer provides for efficient plant design. Proponents must ensure that any preselection or prequalification of MBR components follows the current federal and state procurement laws. Section G1-2.7 provides information regarding Ecology grant and loan eligibility for components identified in plans and specifications based on a preselection process.

To ensure reliability and adequate treatment at all times, engineers must design biological treatment and membrane tanks with sufficient redundancy and flexibility. Such redundancy must follow the general reliability guidelines established in section G.2-8, as well as the reliability guidelines for secondary treatment components (Section T.3-6). Ecology encourages early discussions between project proponents and Ecology engineering staff to assess whether specific design proposals satisfy reliability requirements. In larger systems, engineers must design membrane and biological tanks with flow routing flexibility so that any biological or membrane tank can be removed from service without affecting adjacent processes.

Due to the ability of MBR systems to operate at high MLSS concentrations, hydraulic capacity needs predominantly dictate tank volumes. Specialized needs for advanced nutrient (phosphorus and/or nitrogen) removal also factor into tank volume design. Engineers should design basin volumes based on wastewater characteristics, biological treatment efficiency, treatment flow capacity, and flow variability. Designers must justify that adequate safety factors are used in basin designs to accommodate site-specific flow and organic loading fluctuations. Sludge handling and disposal requirements and local site topography also influence basin designs. Engineers should determine reactor volumes for biological treatment zones in a manner similar to determining basin sizes for conventional activated sludge processes.

Although hydraulic capacity serves as the primary factor for MBR basin sizing, dimension requirements may vary depending on particular MBR system chosen. Where separate membrane tanks are included, membrane tank side wall depths typically range between 8 and 14 feet depending on membrane style and cassette arrangement. Submerged depth for air scour diffusers range between 7 and 10 feet, but may be as deep as 19 feet.

T6-4.5 Pumping Requirements

MBR treatment systems require a variety of pumps for primary fluid flow, recirculation, chemical dispensing and cleaning. Engineers should base decisions for major pumps on the following recommendations. Specific manufacturer or operator requirements may specify additional ancillary pumps.

- **Membrane Feed Pumps:** In applications where the aeration basins are separated from the membrane basins, designs may need to include membrane feed pumps to lift the mixed liquor effluent to the membrane basins. This requirement may result from either membrane manufacturer preference or site conditions that do not allow gravity transfer.
- **Mixed Liquor Recirculation Pumps:** MBR plant designs commonly use submersible or high-capacity end-suction pumps for mixed liquor recirculation. Axial flow pumps are also well suited due to high-flow, low-head requirements. The design engineer will determine specific pump styles for a proposed installation based on site-specific needs. Engineers must size pumps to provide full flow of the recirculation volume and avoid buildup of mixed liquor solids in the membrane tanks. Based on general sludge recirculation requirements, engineers need to size recirculation pumps for flow rates 3 to 6 times the plant flow (3Q-6Q, where Q is design influent flow). Pump designs should consider the use of variable frequency drives (VFD) and incorporation of spare or redundant pumps. Depending on the system design, this function may be accomplished with the Membrane Feed Pumps.
- **Permeate and Back Pulse Pumps:** Engineers may consider permeate pumps dedicated to a single membrane train for simplicity in design and operations. When possible, design should connect pumps to a common permeate header that collects from all of the membranes in a single train. Engineers may either consider end-suction-centrifugal or positive-displacement-rotary-lobe pumps. End-suction-centrifugal pumps may require a means of releasing entrained air, such as a vacuum air separator or a venturi system. Air release is not necessary with self-priming rotary-lobe pumps. Hollow fiber system designs should consider using reversible rotary-lobe pumps to serve the dual options of permeate forward flow and backpulse reverse flow. Designers typically install permeate pumps with variable frequency drives, when economical, and dedicated magnetic flow meters and turbidimeters.
- **Membrane Basin Scum Pumps:** Removal of scum and foam from the membrane tank surface requires scum pumps. Typically, these pumps discharge to the waste activated sludge (WAS) line for further processing.

- **Drain Pumps:** Membrane basins must drain periodically to allow for cleaning and inspection of the tanks and membrane support structures. Ecology recommends that engineers size drain pumps to drain the tanks in 30 minutes or less, minimizing the time membranes are exposed to air to prevent them from drying out.

T6-4.6 Other Support Components

- **Mixers:** Un-aerated (deoxygenation, pre/post anoxic, anaerobic) zones require mixing to ensure solids remain in suspension and to prevent short circuiting through the zone. Some designs may include mechanical mixing in the aeration basins. MBR systems most commonly use submersible mixers.
- **Scum and Foam Handling:** Scum and foam, similar to conventional systems, can present operational problems in MBR systems due to operation at high SRTs. Designers may control scum and foam through surface wasting of excess mixed liquor from either the aeration basin, membrane basin, or both. Engineers may also consider using skimmers for scum and foam control. Residual solids processing strategies determine the preferred scum and foam management design option.
- **Cranes/Hoists:** Individual designs must evaluate the need for periodic removal of membrane cartridges and, if necessary, identify cartridge removal procedure. Periodic cleaning and maintenance of membrane systems may require lifting individual cartridges from the basin. This may occur as frequently as every six months, especially if the modules are located within the aeration basin. To assist this activity, engineers need to design facilities with bridge crane/hoist systems above the basins. The crane/hoist lifting power needs to be designed for the membrane cassette wet weight plus additional weight of the solids accumulated on the membranes. Crane/hoist lifting power needs to incorporate weight of the new generation of the upcoming membrane cassettes which may be heavier than the currently designed cassettes. Engineers may consider other options on a case-by-case basis.
- **Compressed Instrument Air:** Most systems use pneumatically actuated valves and diaphragm pumps for a variety of purposes. A common compressed air system can meet these needs. A common compressed air system consists of a compressor, air dryer, and a dedicated receiver. Typically, instrument air systems operate at 80 psig.

T6-4.7 Disinfection

MBR systems have the capability of removing most bacteria and some viruses. However Ecology requires effluent disinfection because membranes are not an absolute barrier to pathogens. Higher MBR effluent clarity may decrease UV or chlorine dosing requirements. Typically, UV transmissivity for MBR effluents can be approximately 75 percent. This transmissivity is significantly better than filtered conventional activated sludge effluent. Similarly, low particulate concentrations increase the effectiveness of chlorine disinfection. Chapter T-5 provides general requirements for disinfection system design. Chapter E-1 discusses specific disinfection requirements for reclaimed water applications.

T6-5 Operations and Maintenance

T6-5.1 Alarms and Monitoring

Manufacturers typically assemble MBR systems with a variety of integrated sensors and control valves that are tied to a common Programmable Logic Control Center (PLC). The integrated PLC controls critical MBR functions based on alarms and monitoring set points. Typical trend data monitored for automated process control include Trans-membrane Pressure (TMP) (with automated shutdown to respond to failure situations), turbidity, dissolved oxygen, filtrate flow/flux rate, temperature, and permeability. Larger systems with separate monitoring of other unit processes must have the PLC system for the MBRs tied into the facility's Supervisory Control and Data Acquisition (SCADA) system. Operators must understand the operation and actions of the PLC even during unusual events, such as power failures, maintenance of electrical control panels and high flow events.

Proposed designs must include appropriate oxygen monitoring and alarm notification to alert operators to potential oxygen deprivation issues. Typical ranges of oxygen concentrations for treatment zones are:

- Anoxic: 0.0-0.5 mg/L
- Aerobic: 1.5-3.0 mg/L
- Membranes: 1.0-6.0 mg/L

  (Note: Oxygen concentration in membrane basins should be monitored to aid in managing oxygen transfer in recycle flows. However, scouring needs rather than DO concentration drive air flow in the basin.)

T6-5.2 Automation

The vendor's PLC unit automatically controls much of the routine operation of MBR facilities. Typical automated functions include all cleaning cycles except for recovery cleaning (large facilities may choose to include automated recovery cleaning), blower operations, recirculation and permeate pumping, and flow routing in some systems. Plant operators must be trained in all of the normal plant functions in order to identify abnormalities, even though PLC units automatically handle most operations based on pre-programmed variables. Design must provide operators with the ability to alter set-points as treatment goals change or if operator experience indicates a need for process changes.

It is critical that any system have the ability to run in a full manual mode with reasonable effort. Fault tolerance should be reviewed for each system type based on required level of operator oversight to keep a system functional at loss of PLC or communications.

T6-5.3 Flow Control

Engineers should design facility flow to maintain liquid level within a specific range. Designers may set plant automation to place individual membrane trains into standby when influent flow is low. Conversely, when influent flow increases, design should include automatic controls to remove individual trains from standby as needed and, if necessary, to abort cleaning operations. Design may also use automated controls to divert excess influent flow to equalization basins. If the designer provides automated controls with the ability to abort cleaning operations, the design must have appropriate safeguards to ensure proper disposal of cleaning chemicals.

T6-5.4 Power Reliability

All MBR facilities must have sufficient standby power generating capabilities to support all of the plant's critical electrical needs during a power outage. Standby power must be available to serve the needs of all process equipment and critical support equipment. Consult with Ecology's regional engineers and section G.2-8.3 for specific power reliability requirements.

T6-5.5 Membrane Maintenance

In-line turbidity metering of each membrane train provides the primary means of determining major membrane failure and is generally sufficient for all applications. However this method may not identify minor membrane failures. In hollow fiber systems, pressure decay/leak testing using back pressure of 3-9 psi aids in identifying minor defects in individual fibers. Operators must inspect membrane integrity periodically to identify units in need of repair or replacement. No equivalent method has been identified for flat plate systems at this time due to the restriction of backpressure on the membrane design.

Manufacturers specify the nominal frequency of MBR component inspection and maintenance along with the need for specialized tools. Facilities must identify the recommended system maintenance frequency and all specialized tools in their O&M manual. Operators and/or maintenance personnel must have immediate access to any necessary specialized tools.

Current data suggest useful membrane life extends from 5-10 years or more. With proper maintenance by a well-trained operator, the membranes maintain their integrity for many years. However membranes require periodic repair or replacement due to irreversible fouling or physical damage. Due to the delicate construction of most membranes and the potential for damage by operators during routine maintenance, plants must maintain a generous reserve stock of membrane cassettes or modules/plates on hand if the bundles cannot be simply quickly repaired. Approximately 60 percent of membrane replacement over the last 15 years has been associated with mechanical damage during physical cleaning or inspection (Jalla 2005). Inadequate influent screening also contributed to past membrane failure.

T6-5.6 Staffing

The increase in operational and technical complexity of MBR systems requires advanced operator certification, even though most standard MBR processes can be automated. Most installations require at least one operator certified as a group III operator. For large facilities (greater than 10 MGD), Ecology requires operator certification at group IV. Operation by a group II operator is possible with sufficient justification that plant O&M requirements warrant lower certification, and a group III operator or an MBR expert available on-call when needed. Plants must provide sufficient staffing levels to ensure all plant systems receive adequate monitoring and maintenance during normal and unusual operating conditions. Key staff must understand the sequencing and set points of all operations and actions typically controlled by automated systems in order to identify and respond to irregularities.

T6-6 References:

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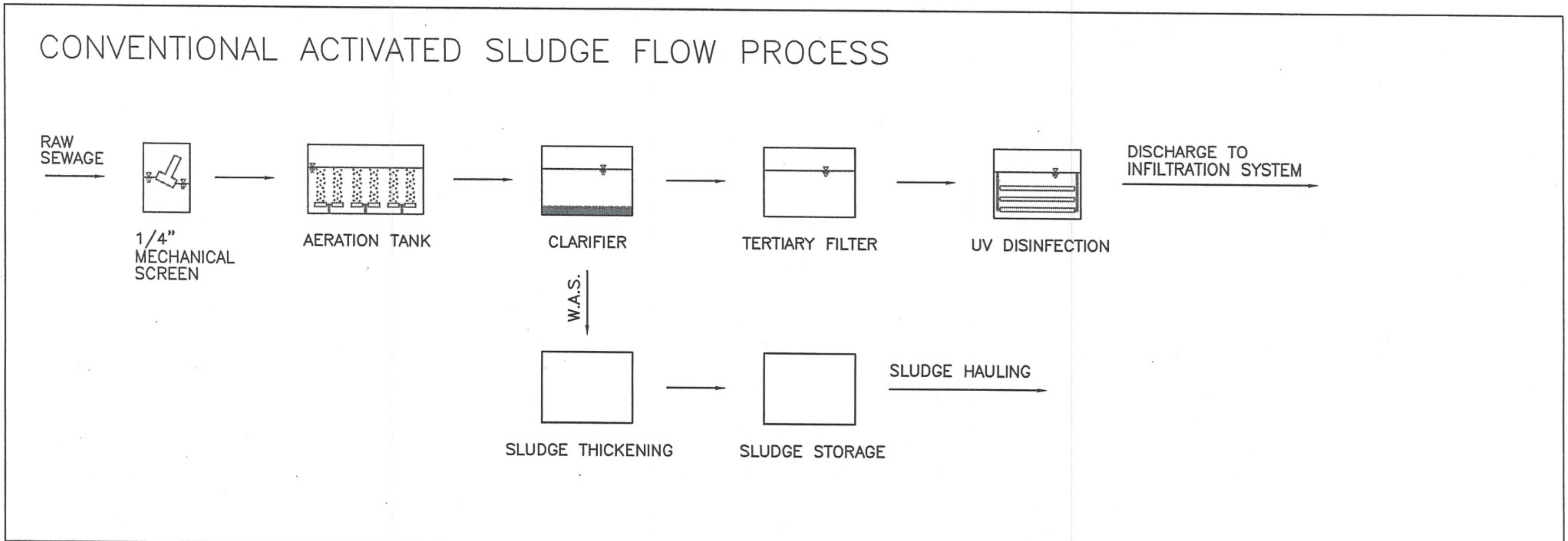
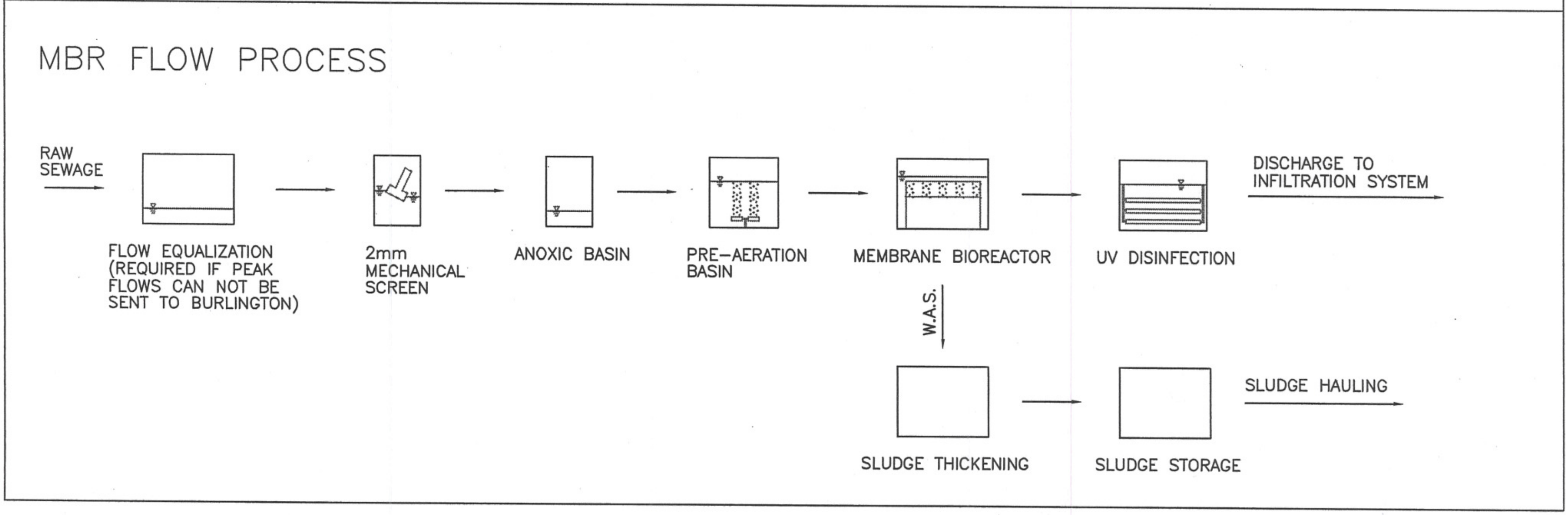
Water Environment Federation, *Membrane Systems for Wastewater Treatment*, Chapter 3, 2005

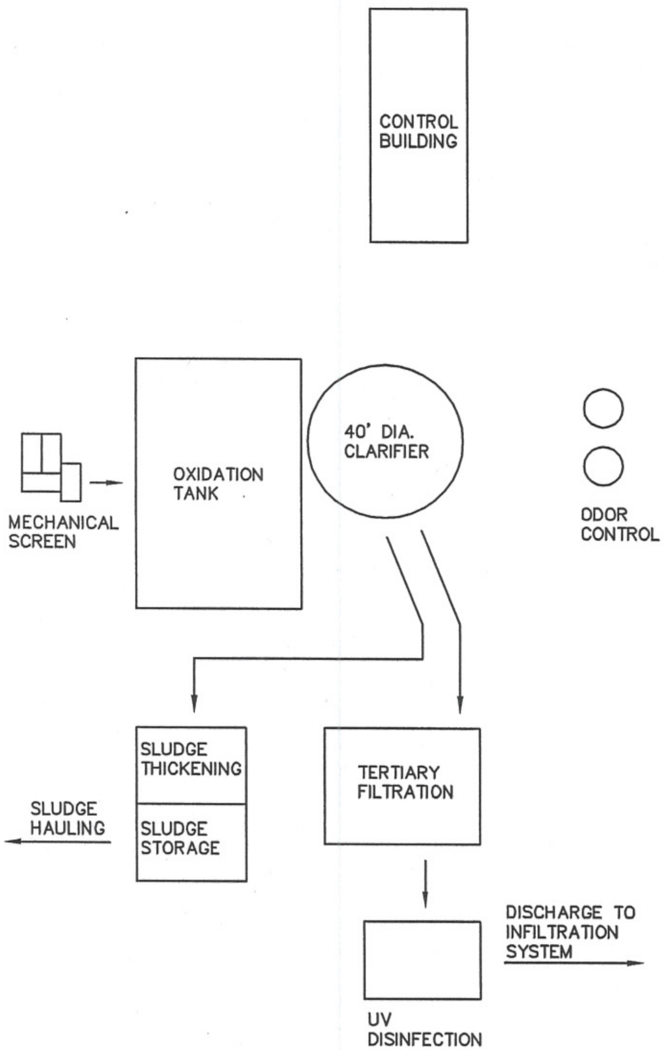
APPENDIX D

APPENDIX D
TREATMENT SYSTEM LAYOUTS
AND FLOW PROCESS DIAGRAMS
CONVENTIONAL ACTIVATED SLUDGE VS MBR

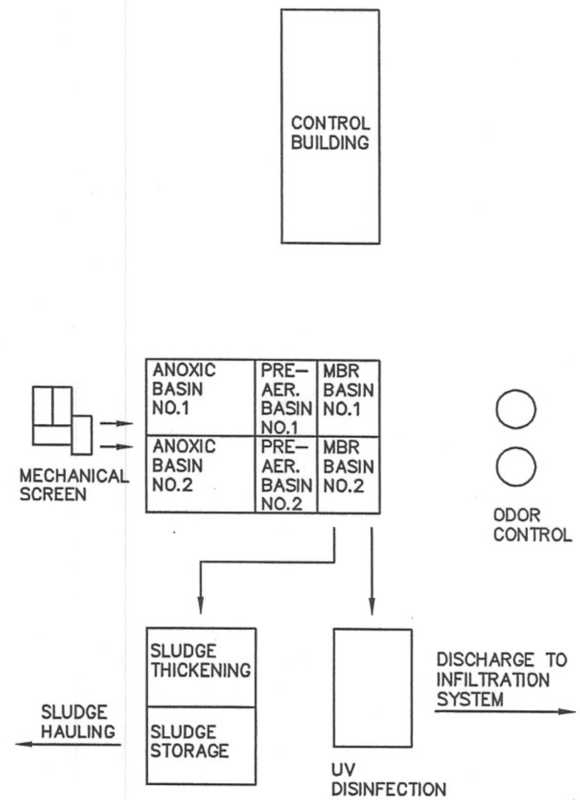

CONVENTIONAL ACTIVATED SLUDGE FLOW PROCESS
RAW SEWAGE
1/4" MECHANICAL SCREEN
AERATION TANK
CLARIFIER
TERTIARY FILTER
UV DISINFECTION
DISCHARGE TO INFILTRATION SYSTEM
W.A.S.
SLUDGE THICKENING
SLUDGE STORAGE
SLUDGE HAULING


MBR FLOW PROCESS
RAW SEWAGE
FLOW EQUALIZATION (REQUIRED IF PEAK FLOWS CAN NOT BE SENT TO BURLINGTON)
2mm MECHANICAL SCREEN
ANOXIC BASIN
PRE-AERATION BASIN
MEMBRANE BIOREACTOR
UV DISINFECTION
DISCHARGE TO INFILTRATION SYSTEM
W.A.S.
SLUDGE THICKENING
SLUDGE STORAGE
SLUDGE HAULING

CONVENTIONAL ACTIVATED SLUDGE TYPICAL WWTP LAYOUT (AVG. FLOW = 400,000 GPD)



MEMBRANE BIOREACTOR TYPICAL WWTP LAYOUT (AVG. FLOW = 400,000 GPD)



APPENDIX E

APPENDIX E
EFFLUENT DISPOSAL ALTERNATIVES AND ASSOCIATED PROJECT PERMITTING & SCHEDULING COMPLEXITY

PROJECT PERMITTING AND SCHEDULING COMPLEXITY

EFFLUENT DISPOSAL SCENARIOS

VERTICAL DISPERSION (SURFACE INFILTRATION)	DEEP INJECTION	HORIZONTAL DISPERSION (SURFACE INFILTRATION?)	HORIZONTAL DISPERSION TO SURFACE WATER DISCHARGE	SURFACE WATER DISCHARGE

PERMITTING REQUIREMENTS

EPA CLASS 5 WELL. UIC PROGRAM	EPA CLASS 5 WELL. UIC PROGRAM	EPA CLASS 5 WELL? UIC PROGRAM?	NPDES PERMIT FOR SURFACE WATER DISCHARGE (EPA/DOE)	NPDES PERMIT (EPA/DOE)

SCHEDULE

N/A. NOT ENOUGH VERTICAL INFILTRATION AVAILABLE ON SITE.	1 TO 2 MONTHS HYDROGEO WORK. IF RESULTS ARE FAVORABLE, WWTP COULD BE ON-LINE BY 2010.	WE CAN TRY THIS APPROACH, HOWEVER, EPA MAY PUSH THIS INTO A NPDES PERMIT CATEGORY.	EPA REPORTS A TREMENDOUS PERMIT BACKLOG. UNDEFINED TIME FRAME. POTENTIAL COMPLICATIONS INCLUDING PUBLIC REVIEW, PUBLIC PROTEST, WATER QUALITY ISSUES (IE TEMP & METALS). RESEARCH REQUIRED FOR BACKGROUND WATER QUALITY.*	SAME AS *

NPDES backlog

Wilson
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BELLINGHAM WASHINGTON
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DATE	SHEET
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SCALE	OF
NTs	
JOB NO.	1
2007-101	

APPENDIX F

APPENDIX F
SURFACE INFILTRATION EVALUATION
"FEBRUARY 20, 2008 POTENTIAL WASTEWATER INFILTRATION EVALUATION"

February 20, 2008
Project No. EH070693A

450,000 gal/day

Wilson Engineering
805 Dupont Street, Suite 7
Bellingham, Washington 98284

Attention: Mr. Jeff Christner

Subject: Potential Wastewater Infiltration Evaluation
Upper Skagit Indian Reservation
Skagit County, Washington

INTRODUCTION AND PROJECT UNDERSTANDING

Associated Earth Sciences, Inc. (AESI) performed a geologic/hydrogeologic assessment of an approximate 115-acre site (herein referred to here as the project site) owned by the Upper Skagit Indian Tribe (Tribe). The project site is located just east of Interstate 5 (I-5), and northeast of the intersection between Bow Hill Road and Darrk Lane in Skagit County, Washington. The approximate location of the project site relative to surrounding physical features is shown on the "Site Vicinity Map," Figure 1. The approximate layout of the site, including the locations of exploration pits completed for this project, is shown on the "Site and Exploration Plan," Figure 2.

We understand that Wilson Engineering is assisting the Tribe in evaluating the potential to infiltrate up to 450,000 gallons per day (gpd) of treated domestic wastewater in the northern portion of the project site. We understand that approximately 171,000 gpd of the treated wastewater will be generated by the Tribe. The remaining 279,000 gpd will be generated by the Samish Water District. The wastewater will be treated using a membrane bioreactor (MBR) wastewater treatment system prior to infiltration. MBR systems have the ability to treat wastewater to a much higher standard than conventional septic systems, resulting in significant reductions in total suspended solids (TSS), biological oxygen demand (BOD), and nitrate-nitrogen in the treated wastewater.

The primary purpose of our services was to evaluate the potential to infiltrate the MBR-treated wastewater at the project site. Our detailed scope of services completed for this project is presented in our approved contract with Wilson Engineering dated October 15, 2006.

INFORMATION REVIEW

We reviewed the following information in the process of completing our geologic/ hydrogeologic assessment of the project site and vicinity:

- *Geologic Map and Interpreted Geologic History of the Bow and Alger 7.5-Minute Quadrangles, Western Skagit County, Washington.* Washington State Division of Geology and Earth Resources Open File Report 98-5, September 1998 (Dragovich, et al., 1998).
- *Geologic Map of the Sedro-Woolley North and Lyman 7.5-Minute Quadrangles, Western Skagit County, Washington.* Washington State Division of Geology and Earth Resources Open File Report 99-3, December 1999 (Dragovich, et al., 1999).
- *Interpreted Geologic History of the Sedro-Woolley North and Lyman 7.5-minute Quadrangles, Western Skagit County, Washington.* Washington State Division of Geology and Earth Resources Open File Report 2000-1, June, 2000 (Dragovich, et al., 2000).
- *Sedro-Woolley North 7.5-Minute Quadrangle Map.* United States Geological Survey (USGS).
- *Soil Survey of Skagit County Area, Washington.* United States Department of Agriculture-Soil Conservation Service (USDA SCS), September 1989.
- Water well reports for the general area on file with the Washington State Department of Ecology (Ecology).

VICINITY AND PROJECT SITE DESCRIPTION

- The project site is located approximately 4 miles northwest of Sedro-Woolley, Washington, and bordered by Bow Hill Road on the south, Darrk Lane on the west, and Old Highway 99 on the East (Figure 1).
- The topography of the project site generally consists of a relatively flat, upland region that drops off steeply into the Friday Creek valley in localized areas along the eastern property boundary (Figure 1).
- The upland portion of the project site is located at elevations ranging between roughly 250 and 280 feet above mean sea level (Figure 2). All elevations referenced in this report are relative to mean sea level unless otherwise noted.

- The steep slopes located along portions of the eastern property boundary were measured at approximate inclinations of 50 to 65 percent, with a total relief of approximately 100 to 120 feet, dropping downward to elevations near 130 feet in the Friday Creek valley (Figure 2).

- The project site is generally undeveloped with thick stands of second and third-growth deciduous trees, some conifers, and moderately thick to thick underbrush. An unpaved access road begins near Highway 99 adjacent to the northeast corner of the site and generally bisects the northern half of the site in an east-west direction. An additional unpaved road provides access to the southern portion of the project site via Darrk Lane and eventually intersects the Highway 99 access road in the north-central portion of the site.

- Most of the upland area in the northern portion of the site appears to be covered with a complex series of shallow, interconnected wetlands.

SURFACE SOILS

Surface soils data were obtained from the *Soil Survey of Skagit County Area, Washington*, prepared by the USDA SCS (USDA, 1989). Individual soil units have been mapped by the SCS on orthophotoquads of the site vicinity. The soils of the project area formed over young glacial or recent stream deposits and have not had sufficient time to develop the deep weathering profiles present in soils in unglaciated terrains. Instead, they exhibit a direct relationship to the underlying parent material, local climate, topography, and vegetation. Soils within the project site consist of the Giles Silt Loam, Hoogdal Silt Loam, and Skipopa Silt Loam. The following is a summary of the soils information for the site.

- The Giles Silt Loam series (30 to 60 percent slopes) is composed of very deep, well-drained soil that develops on terraces. It is formed over glacial outwash deposits. Permeability is moderate and surface water runoff is slow. The SCS lists the Giles soil as having moderate limitations for septic tank adsorption fields. The Giles soils cover a small portion of the site in the very northeastern corner adjacent to Highway 99 in the Friday Creek valley.

- The Hoogdal Silt Loam series is composed of very deep, moderately drained soil that forms on terraces that are underlain by glaciolacustrine and glaciomarine drift. Permeability is slow and surface water runoff is rapid. The SCS lists the Hoogdal soil has having severe limitations for septic tank adsorption fields due to shallow ground water levels and low infiltration rates. The Hoogdal soils are located on the steep slope areas located in the eastern portion of the site (Figures 1 and 2).

- The Skipopa Loam series is composed of a very deep, somewhat poorly drained soil that forms on terraces. The soil develops over glaciolacustrine and glaciomarine drift deposits. Permeability is very slow and surface water runoff is generally slow. The SCS lists the Skipopa soil has having severe limitations for septic tank adsorption fields due to shallow ground water levels and low infiltration rates. The Skipopa soils are the predominant soil at the project site and cover most of the upland area.

FIELD EXPLORATIONS

General

We observed the completion of 22 exploration pits (EP-1 through EP-22) and one infiltration test pit (IT-1) at the project site and vicinity on November 5th and December 5th and 17th of 2007, and January 16th of 2008. A Tribal representative completed the exploration and infiltration pit to depths ranging between 8 and 20 feet below existing grade using a 312C track-mounted excavator. Our field services also included completing a pilot infiltration test (PIT) at the location of IT-1 (Figure 2). Logs of the exploration and infiltration pits are included in Attachment A.

Subsurface Conditions

Subsurface conditions at the project site were inferred from the exploration pits completed for this study, our visual reconnaissance of the site, and applicable geologic literature. Exploration pits EP-1 through EP-11 were completed on the upland area of the project site; EP-13, EP-16, EP-17, and EP-18 were completed on the steep slope area located in the northeast portion of the site; and EP-12, EP-14, EP-15, and EP-19 through EP-22 were completed near the Friday Creek valley floor in the northeast portion of the project site (Figure 2).

Exploration pits EP-1 through EP-11 and EP-17 generally encountered 0.5 to 2.0 feet of topsoil/forest duff overlying medium stiff grading to hard, brown to bluish gray, silt, interpreted as weathered and unweathered glaciomarine drift deposits (Attachment A). The glaciomarine drift extended to the completion depth of these exploration pits. Shallow perched ground water was generally encountered in the exploration pits at depths of less than 2 feet on top of glaciomarine drift.

Exploration pits EP-13 and EP-16 encountered roughly 1 foot of topsoil/forest duff overlying 3 to 14 feet of dense to very dense, gray, silty sand with gravel and few cobbles interpreted as Vashon lodgement till. The lodgement till was underlain by a dense, gray sand and gravel containing trace silts interpreted as Vashon advance outwash (Attachment A). Exploration pits EP-17 and EP-18 encountered approximately 1 foot of topsoil overlying medium stiff grading to stiff, brown to bluish gray silt (glaciomarine drift). The glaciomarine drift was underlain by lodgement till in EP-18.

In the eastern portion of the site, immediately adjacent to Highway 99, exploration pits EP-12, EP-14, EP-15, EP-19 through EP-22, and infiltration test pit IT-1 generally encountered approximately 1 to 2 feet of topsoil that was underlain by 2 to 10 feet of brown to orange-brown, medium stiff to stiff silt with sand and gravel that is interpreted to be relatively recent overbank flood deposits associated with Friday Creek. The overbank sediments were underlain by gray, medium dense to dense sand and gravel with varying amounts of silt, cobbles, and boulders that were interpreted as recent alluvium from nearby Friday Creek. Ground water seepage was observed ranging from 3.5 to 10 feet below existing grade in EP-14, EP-20, EP-22, and IT-1. No ground water seepage was encountered in explorations EP-12 through EP-14, EP-16, or EP-21.

Infiltration Test

An infiltration test was conducted in IT-1 located in the northeast portion of the project site on January 16, 2008 (Figure 2). The test was performed using the test pit methods that generally correspond to the procedure described as a PIT in the 2005 Washington State Department of Ecology *Stormwater Management Manual for Western Washington* (Ecology Manual). The procedures for each testing method are described below.

- One shallow infiltration pit (IT-1) of known dimensions was excavated to a depth of 5.5 feet, respectively, at the location shown on Figure 2. The base of the infiltration pit was completed within a relatively permeable, fine to coarse sand with gravel unit containing few cobbles and boulders and trace amounts of silt (Attachment A).

- A staff gauge with 0.01-foot divisions was placed into the base of the infiltration pit to measure the depth of water during the test.

- The infiltration pit was filled with water from a subcontracted water truck to a pre-determined head level, where the water level was maintained by adjusting the flow of water into the pit.

- An electronic flow meter/totalizer was used to monitor the water discharge rate and total flow required to maintain the constant head in the pit.

- The water level was held at the pre-determined head level for approximately 5 hours during the constant-head test portion of the infiltration test.

- Following the constant-head test period, discharge into the pit was discontinued, and the water level in the pit was monitored at timed intervals to determine the falling-head rate.

- Upon completion of the infiltration test, the infiltration pit was overexcavated to: (1) document the types of soils the water infiltrated through, and (2) identify any soil layers that may restrict the downward flow of infiltrating water.

The saturated infiltration rate (vertical hydraulic conductivity) was calculated using a constant-head analysis. The falling-head rate estimated from the late stages of the testing period was used as a verification of the constant-head infiltration rate. The vertical infiltration rates for the project site ranged from 0.1 inches per hour (in/hr) with 2 feet of head to 0.22 in/hr with approximately 2.5 feet of head, based on the constant-head infiltration test. A summary of the constant- and falling-head infiltration rates estimated from the on-site testing are presented in Table 1.

Table 1
Infiltration Test Results

Infiltration Test	Test Depth (feet)	Water Volume Used (gallons)	Constant-Head Infiltration Rate (inches/hour)	Falling-Head Infiltration Rate (inches/hour)
IT-1	5.5	762	0.1 to 0.22	0

GEOLOGIC AND HYDROGEOLOGIC CONDITIONS

Geology

The project site is situated adjacent to the Friday Creek/Samish River valley in what is generally considered to be the northern margin of the Skagit River drainage. The Skagit River extends from southern British Columbia, south and westward into the Puget Lowland. The Puget Lowland is a portion of a regional, north-south trending topographic trough that extends from the Fraser River valley to northern Oregon. The Skagit and Samish River valleys are contained by steep mountains that rise above the valley bottoms to elevations greater than 4,000 feet in many locations. Bedrock is generally present at the ground surface above elevations of approximately 500 feet. The mountains located to the east and northeast of the project site consist of a complex assemblage of volcanic, metamorphic, igneous, and sedimentary rocks. The valley bottom to the south and southwest of the project site is underlain by several tens and possibly hundreds of feet of glaciofluvial sediments and recent river alluvium. Relatively impermeable bedrock underlies the glaciofluvial/alluvium at depth.

Geologic maps of the project site vicinity (Dragovich, et al., 1998) and our site observations indicate that most of the project site is underlain by Everson-age glaciomarine drift. The glaciomarine drift appears to be several tens of feet thick and is underlain by Vashon-age lodgement till in local areas. Information presented on water well reports for wells located in the project vicinity and our on-site observations indicate that the glaciomarine drift and till units combined are as much as 90 feet thick beneath the upland area in the immediate vicinity of the site.

The glaciomarine drift was deposited from the melting of continental glaciers as they "floated" on seawater approximately 11,000 years ago. The glacial till was deposited beneath the continental glacial ice sheet as it advanced across the Puget Sound region roughly 15,000 years ago. Both the glaciomarine drift and glacial till contain a high percentage of fine-grained sediments and, consequently, have very low permeabilities. Vashon till, overlain by glaciomarine drift, was encountered in EP-13, EP-16, and EP-18 near the ground surface in the steep slope area along the eastern boundary of the site (Figure 2, Attachment A).

The glaciomarine drift and/or till are underlain by Vashon-age advance outwash. The advance outwash deposits accumulated in glaciofluvial environments (meltwater streams) that formed in front of the above-mentioned advancing continental glacier. As the Vashon-age glacier spread into the region, the advance outwash sediments were consolidated into a dense condition by several thousand feet of ice. Water well reports for the area indicate that the advance outwash is at least 10 feet thick and likely is underlain by pre-Vashon sand and gravel deposits. The advance outwash is locally exposed at the ground surface in the steep slope area in the eastern portion of the project site and was encountered in EP-13 and EP-16 (Attachment A).

Much of the very eastern portion of the site located in the Friday Creek valley is covered at the ground surface by recent overbank flood deposits and alluvial sediments deposited by the ancestral Friday Creek. The overbank deposits generally consisted of low permeability silt with some fine sand. The alluvium generally consisted of sand and gravel with varying amounts of silt.

Hydrogeology

General

Our review of available information for the project site, our site observations/explorations, and our experience in the area indicate that the site is underlain by (1) a shallow perched aquifer located on top of the relatively low permeability glaciomarine drift and/or glacial till units on the upland portion of the site; (2) a deeper aquifer located within the advance outwash/older pre-Vashon sediments; and (3) a shallow aquifer located in the alluvial sediments located in the Friday Creek valley. The following is a brief summary of the pertinent characteristics of the identified aquifers.

Shallow Perched Aquifer

- A localized, shallow perched aquifer appears to have formed where precipitation has infiltrated through the 1 to 2 feet of relatively permeable topsoil/weathered glaciomarine drift soils and has encountered the top of low-permeability, unweathered glaciomarine drift and/or glacial till that appears to underlie the upland portion of the project site.

- The perched ground water appears to generally flow south and southeast towards the Friday Creek and Samish River valleys. It is also possible that some of the perched ground water in the very northern portion of the site flows off-site to the north and northeast. The perched aquifer flow direction is likely controlled by the topography of the top of the underlying glaciomarine drift/glacial till, which likely generally mimics the ground surface topography beneath the project site.

- The seasonal high ground water levels in the perched aquifer appear to be roughly 1 foot below the ground surface during the winter months of the year and likely 1 to 2 feet below the ground surface in the summer and late fall months.

- Recharge to the shallow perched aquifer is from the direct infiltration of precipitation.

- The perched aquifer is in continuity with and generally discharges to the abundant wetlands located on the upland portion of the site. The shallow aquifer likely also discharges in local areas to springs and seeps in the steep slope areas of the site.

- The perched aquifer may also provide some recharge to deeper aquifers located beneath the site by vertical infiltration. However, due to the relatively low permeability of the underlying glaciomarine drift and/or glacial till, it is our opinion that vertical recharge to deeper aquifers is relatively insignificant.

Vashon Advance Outwash

- The top of the advance outwash appears to be located at depths of 50 to 80 feet beneath the upland portion of the project site based on information presented on water well reports and our on-site explorations.

- The ground water levels in the advance outwash appears to be at depths ranging between approximately 80 and 200 feet based on limited information available for nearby water wells.

- The saturated portion of the outwash is likely a few tens of feet thick and it may co-mingle with underlying, permeable, older, pre-Vashon sand and gravel deposits.

- The ground water in the advance outwash likely flows to the south and/or southwest beneath the site and ultimately discharges to alluvium located in the Friday Creek and/or Samish River valleys.

- Recharge to the advance outwash beneath the site is by ground water throughflow with a minor amount of vertical recharge from the overlying perched aquifer.

Alluvial Aquifer

- The alluvial aquifer is located at a depth of approximately 5 feet in the northeastern portion of the site located in the Friday Creek valley. The aquifer is generally overlain by roughly 2 to 10 feet of low permeability silt overbank sediments.

- The alluvial aquifer is likely at least several tens of feet thick and it may co-mingle with underlying, permeable, advance outwash and older, pre-Vashon sand and gravel deposits.

- Ground water in the alluvial aquifer likely flows generally to the south in the Friday Creek valley and ultimately discharges into either Friday Creek and/or the Samish River.

- The ground water levels in the alluvial aquifer encountered at the project site appear to be at depths ranging between approximately 4 and 10 feet based on subsurface conditions encountered in the exploration pits (Attachment A).

- Recharge to the alluvial aquifer is from vertical recharge of precipitation and ground water throughflow from the adjacent advance outwash aquifer.

CONCLUSIONS AND RECOMMENDATIONS

Infiltration Potential – Upland Area

- Information gained from the test pit explorations and our site observations indicate that it may be possible to infiltrate some of the proposed treated effluent into the unsaturated upper 1 to 2 feet of the soil column in the upland area of the site.

- As previously discussed, much of the upland area is covered with shallow, interconnected wetlands. Our site observations indicate that it may be possible to infiltrate the treated effluent in topographically elevated areas that are separated horizontally from the nearby wetlands by as much as a few tens of feet.

- Treated effluent infiltrated into the upper zone will migrate horizontally and ultimately discharge into the nearby wetlands within a few hours. The subsurface migration of the treated effluent would moderate the water temperature to near background levels prior to discharge to the wetlands. The interconnected nature of the wetlands would likely result in the wastewater being distributed relatively equally over the target area.

- Infiltrating/distributing approximately 450,000 gpd of treated effluent over roughly 20 acres located in the northwest portion of the site would result in a loading rate of roughly 0.83 inches per day (in/d).

- Infiltrating/distributing the Tribe's portion of the treated wastewater (171,000 gpd) over the 20 acres would result in an approximate loading rate of 0.31 in/d.

- The infiltrated/dispersed treated wastewater would likely exit the upland portion of the site via evapotranspiration by plants, direct evaporation off of open water in the wetlands, and as surface water runoff associated with the existing wetlands.

- We recommend that treated effluent not be infiltrated on the upland area within 200 feet of the steep slopes located in the eastern portion of the project site to minimize potential impacts to slope stability.

Infiltration Potential – Friday Creek Valley

- The subsurface conditions observed in several exploration pits (EP-12, EP-14, EP-15, and EP-19 through EP-22) indicated that it may be possible to infiltrate some treated effluent in the portion of the site that is located in the Friday Creek valley (Figure 2).

- The recent alluvial material is the potential target unit for infiltration in the Friday Creek valley. As previously discussed, the alluvial sediments are located at depths ranging between approximately 5 and 10 feet, and consist of sand and gravel with lenses of silt.

- The infiltration testing in IT-1, completed in upper portion of the alluvial sediments, indicated a relatively low vertical infiltration rate (maximum rate of 0.22 in/hr). It should be noted that the vertical infiltration rate is a field-measured, in situ infiltration rate and should not be considered a design rate, as it may overestimate long-term infiltration rates.

- Approximately 90,000 square feet of the project site is located in the Friday Creek valley. Assuming a long-term infiltration rate of 0.06 in/hr (1/4 the maximum in-field measured rate) indicates that roughly 45 percent of the Tribe's expected volume of treated effluent (maximum total of approximately 80,000 gpd) could potentially be infiltrated at the site.

- Some portion of the treated effluent infiltrated into the upper zone in the Friday Creek valley portion of the site would exit the site as evapotranspiration; however, the vast majority of the treated effluent would likely migrate as subsurface storm flow toward the south and ultimately discharge into the wetland area located immediately south of the project site, just to the west of Highway 99.

- We recommend that treated effluent not be infiltrated on the steep slopes located adjacent to the Friday Creek portion of the upland area.

LIMITATIONS

We have prepared this report for the Upper Skagit Indian Tribe and their consultants for use in evaluating options for the disposal of treated wastewater at the project site. The conclusions and interpretations presented in this report should not be construed as a warranty of the subsurface conditions. Our conclusions and recommendations are based on a baseline of limited on-site information and on information provided by various other consultants and the Tribe. Much analysis presented in this report is based on a limited number of explorations, and our experience has shown that soil and ground water conditions can vary significantly over small distances. Inconsistent conditions can occur between explorations that may not be detected by a hydrogeologic study. If, during future site operations, subsurface conditions are encountered that vary appreciably from those described herein, AESI should be notified for review of the recommendations of this report and revisions of such, if necessary.

Within the limitations of scope, schedule, and budget, AESI attempted to execute these services in accordance with generally accepted professional principles in the field of hydrogeology at the time this report was prepared. No warranty, express or implied, is made.

We have enjoyed working with you on this study and are confident that the conclusions presented in this report will aid in the successful completion of your project. If you should have any questions or require further assistance, please do not hesitate to call.

Sincerely,
ASSOCIATED EARTH SCIENCES, INC.
Everett, Washington

State of Washington
Hydrogeologist
617
Licensed Geologist
Charles S. Lindsay

for

Jon D. Hansen
Senior Staff Geologist

Charles S. Lindsay, P.G., P.E.G., P.Hg.
Principal Geologist/Hydrogeologist

Attachments:	Figure 1:	Site Vicinity Map
	Figure 2:	Site Exploration Plan
	Attachment A:	Exploration and Infiltration Pit Logs

JDH/ts - EH070693A11 - Projects\20070693\EH\WP

Reference: USGS Alger 7.5 Minute Quadrangle Map

North

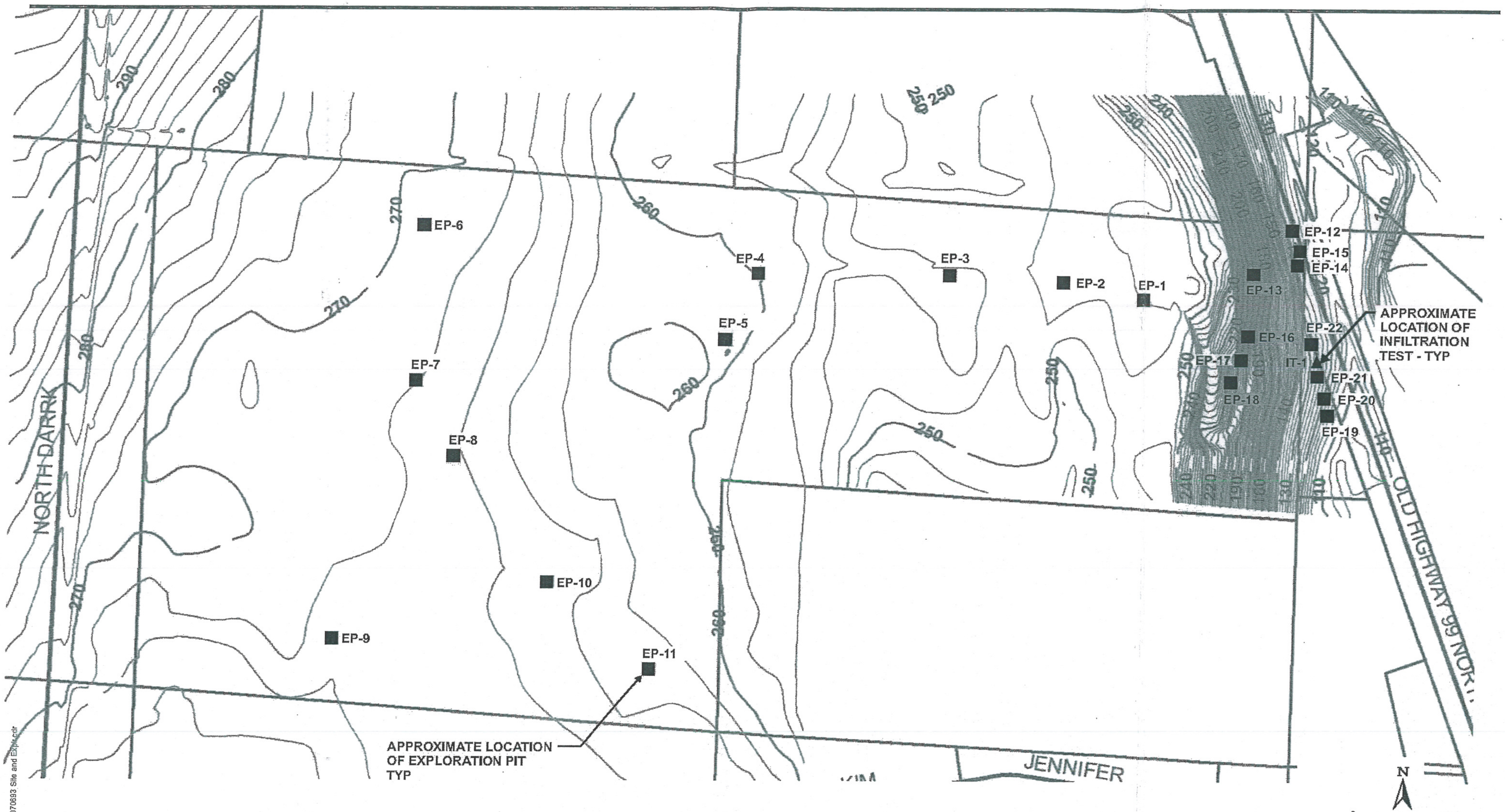
Scale
0 2000
(feet)

Associated Earth Sciences, Inc.

Site Vicinity Map

FIGURE 1

AESI Project No. EH070693A – Figure 1



Reference: Street centerlines, parcel outlines - Skagit County GIS Center

070693 Wastewater Infiltration \ 070693 Site and Expl.cdr

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SITE AND EXPLORATION PLAN
WASTEWATER INFILTRATION EVALUATION
SKAGIT COUNTY, WASHINGTON

FIGURE 2
DATE 2/08
PROJ. NO. EH070693A

LOG OF EXPLORATION PIT NO. EP-12

Depth (ft)	This log is part of the report prepared by Associated Earth Sciences, Inc. (AESI) for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this trench at the time of excavation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered. **DESCRIPTION**
1	**Topsoil** Loose, moist, brown, silty SAND, few gravel, few organics.
2	**Overbank Deposits** Medium dense, moist, orangish brown, silty SAND, few gravel, trace rootlets (SM).
3	**Alluvium** Medium dense to dense, moist, gray, silty SAND, few to little gravel, trace cobbles.
4	
5	
6	
7	
8	
9	
10	
11	Bottom of exploration pit at depth 10 feet Roots to 3 feet bgs. No caving. No seepages.
12	
13	
14	
15	
16	
17	
18	
19	
20	

KCTP3 070693A.GPJ February 13, 2008

Wastewater Infiltration Evaluation
Skagit County, WA

Logged by: JDH

Approved by:

Associated Earth Sciences, Inc.

Project No. EH070693A

12/5/07

LOG OF EXPLORATION PIT NO. EP-14

Depth (ft)	This log is part of the report prepared by Associated Earth Sciences, Inc. (AESI) for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this trench at the time of excavation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplification of actual conditions encountered. **DESCRIPTION**
	Topsoil
1	Loose, moist to very moist, dark brown, silty SAND, trace to few gravel, trace organics.
	Overbank Deposits
2	Medium stiff, moist to very moist, brown, SILT, trace to few gravel, trace rootlets (ML).
3	**Alluvium**
4	
5	Stiff, moist to very moist, light gray, SILT, trace to few gravel, mottled.
6	
7	
8	
9	
10	
11	
12	
13	Bottom of exploration pit at depth 12 feet Roots to 3 feet bgs. No caving. No seepage.
14	
15	
16	
17	
18	
19	
20	

Wastewater Infiltration Evaluation
Skagit County, WA

Associated Earth Sciences, Inc.

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Project No. EH070693A

12/5/07

LOG OF EXPLORATION PIT NO. EP-15

Depth (ft)	This log is part of the report prepared by Associated Earth Sciences, Inc. (AESI) for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this trench at the time of excavation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplification of actual conditions encountered. **DESCRIPTION**
	Topsoil
1	Loose, moist, dark brown, silty SAND, few gravel, few roots.
2	**Overbank Deposits**
3	Medium stiff, moist to very moist, orangish brown, SILT, few gravel, trace cobbles (ML).
4	**Alluvium**
5	Stiff, moist, gray, SILT, few gravel, trace cobbles, mottled.
6	
7	
8	
9	
10	Dense, very moist to wet, silty GRAVEL, with sand, trace cobbles, slight mottling (GM).
11	
12	
13	
14	
15	Bottom of exploration pit at depth 14.5 feet Roots to 3 feet bgs. Slight seepage at 14 feet bgs. Slight caving at 10 feet.
16	
17	
18	
19	
20	

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Wastewater Infiltration Evaluation
Skagit County, WA

Associated Earth Sciences, Inc.

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LOG OF EXPLORATION PIT NO. EP-16

Depth (ft)	DESCRIPTION
	This log is part of the report prepared by Associated Earth Sciences, Inc. (AESI) for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this trench at the time of excavation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered.
	Topsoil
1	Loose, moist, brown, silty SAND, with gravel, trace organics.
	Vashon Lodgement Till
2	Dense to very dense, moist, brown/gray, silty SAND, with gravel, slightly mottled (SM).
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	**Vashon Advance Outwash**
16	Dense, very moist to wet, gray SAND and GRAVEL, trace silt (SW).
17	
18	
19	
20	
21	Bottom of exploration pit at depth 20 feet Surficial roots. No caving. No seepage.
22	
23	
24	
25	

LOG OF EXPLORATION PIT NO. EP-18

Depth (ft)	This log is part of the report prepared by Associated Earth Sciences, Inc. (AESI) for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this trench at the time of excavation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered. **DESCRIPTION**
	Topsoil
1	Soft, moist to very moist, dark brown, SILT, few organics.
	Glaciomarine Drift
2	Medium stiff to stiff, moist to very moist, light gray/brown, SILT, slightly mottled (ML).
	Vashon Lodgement Till
3	Dense to very dense, moist, gray, silty SAND, with gravel, few cobbles, mottled.
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	Bottom of exploration pit at depth 15 feet Surficial roots. No caving. Slight seepages in roots zones.
17	
18	
19	
20	

KCTP3 070693A.GPJ February 6, 2008

Wastewater Infiltration Evaluation
Skagit County, WA

Associated Earth Sciences, Inc.

Logged by: JDH

Approved by:

Project No. EH070693A

12/5/07

LOG OF EXPLORATION PIT NO. EP-19

Depth (ft)	This log is part of the report prepared by Associated Earth Sciences, Inc. (AESI) for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this trench at the time of excavation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered. **DESCRIPTION**
	Topsoil Soft, moist to very moist, brown to dark brown, fine sandy SILT, trace to few organics, trace gravel.
1	**Overbank Deposits**
2	Stiff to very stiff, moist, gray/brown, SILT, trace to few gravel, trace rootlets, mottled (ML).
3	
4	
5	
6	
7	
8	**Alluvium**
9	Dense, very moist to wet, gray, silty GRAVEL, few cobbles, trace boulders (subrounded to rounded), mottled (GM).
10	
11	
12	
13	
14	
15	
16	Bottom of exploration pit at depth 15 feet Slight caving at 10 feet. Small seepage at 10 feet. Roots to 2 feet.
17	
18	
19	
20	

Wastewater Infiltration Evaluation
Skagit County, WA

Associated Earth Sciences, Inc.

Logged by: JDH

Approved by:

Project No. EH070693A

12/17/07

LOG OF EXPLORATION PIT NO. EP-21

This log is part of the report prepared by Associated Earth Sciences, Inc. (AESI) for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this trench at the time of excavation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered.

Depth (ft)	DESCRIPTION
	Topsoil
1	Soft, moist to very moist, brown, fine sandy SILT, few gravel, trace to few organics.
	Overbank Deposits
2	Stiff, moist, brown, fine sandy SILT, few gravel, trace to few cobbles, slightly mottled (ML).
3	
4	**Alluvium**
5	Dense, very moist to wet, silty GRAVEL, few fine to coarse sand, few cobbles, trace to few boulders (GM).
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	Bottom of exploration pit at depth 14 feet Slight caving at 6 feet. No seepages. Roots to 2 feet.
16	
17	
18	
19	
20	

Wastewater Infiltration Evaluation
Skagit County, WA

Associated Earth Sciences, Inc.

Logged by: JDH

Approved by:

Project No. EH070693A

12/17/07

KCTP3 070693A.GPJ February 13, 2008

LOG OF EXPLORATION PIT NO. EP-22

This log is part of the report prepared by Associated Earth Sciences, Inc. (AESI) for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this trench at the time of excavation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered.

Depth (ft)	DESCRIPTION
	Topsoil
1	Loose, moist, brown to dark brown, silty fine SAND, trace to few gravel, trace to few organics.
	Overbank Deposits
2	Medium dense, moist, brown to orangish brown, silty fine SAND, little gravel, trace to few cobbles (SM).
3	**Alluvium**
4	Becomes dense, moist, gray, silty fine SAND, few to little gravel, few cobbles, trace to few boulders.
5	
6	Cobbles and boulders.
7	
8	Grades to dense, very moist to wet, SAND and GRAVEL, few silts, trace cobbles.
9	
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18	
19	Bottom of exploration pit at depth 18 feet Slight caving at 7 feet. Seepage at 8 feet. Roots to 2.5 feet.
20	

Wastewater Infiltration Evaluation
Skagit County, WA

Associated Earth Sciences, Inc.

Logged by: JDH

Approved by:

Project No. EH070693A

12/17/07

KCTP3 070693A.GPJ February 13, 2008

LOG OF EXPLORATION PIT NO. IT-1

Depth (ft)	This log is part of the report prepared by Associated Earth Sciences, Inc. (AESI) for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this trench at the time of excavation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered. **DESCRIPTION**
	Topsoil Loose, very moist, dark brown, silty fine SAND, trace to few organics, trace gravel.
1	**Overbank Deposits**
2	Medium dense, moist to very moist, light brown and gray, silty fine SAND, trace gravel, slight mottling throughout (SM).
3	**Alluvium**
4	Dense, very moist to wet, brown, fine to coarse SAND, with gravel, few cobbles, few boulders, trace to few silt (SW).
5	
6	Grades to dense, wet, gray, fine to coarse SAND, with gravel, trace cobbles, trace silts (SP).
7	
8	
9	Bottom of exploration pit at depth 8 feet Slight caving at 5.5 feet. Small perched seepage at 3 feet and 15.5 feet and seepage at 6.5 feet. Roots to 1.5 feet. Infiltration test at 5.5 feet.
10	
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Wastewater Infiltration Evaluation
Skagit County, WA

Logged by: JDH

Approved by:

Associated Earth Sciences, Inc.

Project No. EH070693A

1/16/08

APPENDIX G

APPENDIX G
UPPER SKAGIT INDIAN TRIBE METALS IN RAW WASTEWATER AND ASSOCIATED SURFACE WATER DILUTION REQUIREMENTS

Upper Skagit Tribe
Metals in Wastewater (per 10/17/07 Sample)
Date: February 15, 2008

Allowable Metal Limits	Sample Results (11/27)	Violation per WA State Water Quality Criteria (WAC 173-201A-240)	Surface Water Dilution Needed
Assumed hardness for surface water = 20			USIT Flow = 171,000 gpd = 0.26 cfs
Copper	Copper	Copper	Copper
0.00287 mg/L (Chronic, 4-day avg.)	0.047 mg/L	16.4 times Chronic Level	17.3 cfs
0.00374 mg/L Acute (1-hr avg.)		12.6 times Acute Level	133.2 cfs
Zinc	Zinc	Zinc	Zinc
0.02672 mg/L (Chronic, 4-day avg.)	0.19 mg/L	7.1 times Chronic Level	7.5 cfs
0.02927 mg/L Acute (1-hr avg.)		6.5 times Acute Level	68.7 cfs
Lead, CF = 1.02552	Lead	Lead	Lead
0.00042 mg/L (Chronic, 4-day avg.)	0.001 mg/L	2.4 times Chronic Level	2.5 cfs
0.01079 mg/L Acute (1-hr avg.)		N/A Acute Level	0.0 cfs

Allowable Metal Limits	Sample Results (11/27)	Violation per WA State Water Quality Criteria (WAC 173-201A-240)	Surface Water Dilution Needed
Assumed hardness for surface water = 100			USIT Flow = 171,000 gpd = 0.26 cfs
Copper	Copper	Copper	Copper
0.01136 mg/L (Chronic, 4-day avg.)	0.047 mg/L	4.1 times Chronic Level	4.4 cfs
0.01702 mg/L Acute (1-hr avg.)		2.8 times Acute Level	29.2 cfs
Zinc	Zinc	Zinc	Zinc
0.10451 mg/L (Chronic, 4-day avg.)	0.19 mg/L	1.8 times Chronic Level	1.9 cfs
0.11445 mg/L Acute (1-hr avg.)		1.7 times Acute Level	17.6 cfs
Lead, CF = 0.79100	Lead	Lead	Lead
0.00252 mg/L (Chronic, 4-day avg.)	0.001 mg/L	N/A Chronic Level	0.0 cfs
0.06458 mg/L Acute (1-hr avg.)		N/A Acute Level	0.0 cfs

Washington State Dept. of Ecology — HYDAY V95 Output 11/03/2008

Site 03C060 — Friday Creek below Hatchery — Year 2006/07
VarFrom 232.00 — Raw Stage in Feet — Table Type Rate
VarTo 262.00 — Discharge in Cubic feet/second, Measured
Figures are for period ending 2400 hours.

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Day
1	8.3*	6.6~	177*	121~	80.0~	128~	118~	48.1~	12.9~	10.5~	5.0~	3.7U	1
2	7.7*	6.8~	155*	425J	74.3~	116~	108~	47.4~	12.3~	7.9~	4.8~	3.9U	2
3	7.2*	14.7~	146~	624J	70.7~	120~	97.4~	43.4~	11.6~	6.9~	4.9~	3.8U	3
4	6.7*	52.9~	145~	508J	72.3~	110~	89.8~	41.4~	11.6~	6.4~	4.4U	4.5U	4
5	6.3*	85.7~	150~	402J	71.3~	112~	79.9~	38.1~	11.7~	6.1~	4.1U	4.6~	5
6	5.9*	331J	144~	563J	66.7~	101~	73.6~	36.8~	11.6~	5.6~	4.1U	4.5U	6
7	5.5*	370A	138~	713J	63.3~	98.9~	71.8~	36.8~	12.2~	5.3~	4.1U	4.1U	7
8	5.1*	237A	137~	615J	63.8~	145~	68.6~	32.9~	11.2~	4.8~	4.6~	4.0U	8
9	4.7*	174~	129~	435A	61.3~	115~	92.1~	32.1~	11.9~	4.1U	4.4U	4.0U	9
10	4.1L	154~	122~	344A	58.6~	107~	81.6~	29.9~	12.4~	3.8U	4.1U	3.8U	10
11	4.7B	213~	128~	280A	56.2~	209~	70.2~	27.7~	12.3~	3.9U	3.9U	3.8U	11
12	17.1L	329J	151~	233~	53.5~	215~	64.3~	26.3~	10.8~	3.8U	3.7U	3.8U	12
13	22.0~	602J	229A	199~	50.3~	184~	60.4~	24.2~	10.5~	4.1U	3.6U	3.8U	13
14	21.7~	404A	264A	171~	57.6~	196~	60.9~	23.4~	9.9~	4.4U	3.7U	3.9U	14
15	27.1~	297L	316A	150~	175~	157~	57.2~	22.4~	10.6~	4.2U	3.8U	4.0U	15
16	25.8~	266A	237~	138~	160~	161~	54.4~	20.5~	10.4~	4.2U	3.7U	4.7U	16
17	21.9~	219~	197~	133~	112~	199A	62.0~	19.6~	11.1~	4.9U	3.7U	5.6~	17
18	21.3~	195~	170~	178~	135~	252A	59.1~	18.9~	10.9~	5.7~	3.7U	5.2~	18
19	26.8~	174~	154~	275A	183A	198~	55.0~	19.0~	9.7~	9.7~	3.9U	5.2~	19
20	22.1~	159~	142~	307A	294A	186~	53.0~	20.6~	8.7~	9.1~	4.1U	5.1~	20
21	17.0~	153~	153~	216~	228~	159~	52.6~	35.9~	8.2~	10.5~	5.5~	5.8~	21
22	15.4~	145~	159~	191~	184~	160~	49.6~	28.5~	8.2~	12.9~	5.2~	7.6~	22
23	12.9~	168~	198~	212~	199~	204A	36.3~	26.9~	9.2~	11.3~	4.4U	6.7~	23
24	11.8L	204~	194~	187~	238~	589J	24.2~	21.8~	10.2~	9.8~	4.1U	5.8~	24
25	11.4~	240~	250~	161~	233~	530J	25.3~	19.6~	11.1~	8.3~	4.3U	5.6~	25
26	11.1~	247A	206~	144~	196~	321A	27.9~	18.1~	8.8~	7.1~	5.1~	5.5~	26
27	10.6~	235~	207~	128~	165~	242~	33.3~	20.9~	8.1~	6.2~	4.6~	6.0~	27
28	10.5~	191~	171~	115~	143~	198~	76.3~	17.5~	8.0~	6.0~	4.1U	8.1~	28
29	15.0~	154~	151~	105~		170~	57.1~	15.6~	8.5~	6.0~	4.0U	6.8~	29
30	12.4~	172*	137~	95.1~		149~	49.4~	14.7~	9.9~	6.0~	3.9U	12.6~	30
31	9.6~		122~	86.8~		134~		13.8~		5.5~	3.7U		31
Mean	13.2L	207J	174*	273J	127A	192J	63.6~	27.2~	10.5~	6.6U	4.2U	5.2U	
Median	11.4L	193J	154*	199J	96.2A	161J	60.6~	24.2~	10.7~	6.0U	4.1U	4.7U	
Max.Daily Mean	27.1L	602J	316*	713J	294A	589J	118~	48.1~	12.9~	12.9U	5.5U	12.6U	
Min.Daily Mean	4.1L	6.6J	122*	86.8J	50.3A	98.9J	24.2~	13.8~	8.0~	3.8U	3.6U	3.7U	
Inst.Max	33.6L	722J	417*	979J	326A	808J	125~	49.8~	14.7~	15.4U	6.8U	23.6U	
Inst.Min	3.6L	6.1J	113*	83.2J	47.8A	91.5J	20.7~	8.4~	7.3~	2.5U	3.4U	3.6U	

Summaries

	Maximum	Minimum
Annual Mean	91.8U	
Ann. Median	33.3U	
Daily Mean	713U	3.6U
Instant	979U	2.5U

----------------- Notes -------------------

All recorded data is continuous and reliable except where the following tags are used...

- * ... Data estimated based on other stations
- A ... Above Rating, reliable extrapolation
- B ... Below rating, reliable extrapolation
- J ... Estimated Data
- L ... Linear interpolation across gap in dat
- U ... Unknown flow, less than value shown
- ~ ... Provisional data

APPENDIX H

APPENDIX H
SLUDGE PRODUCTION CALCULATIONS

USIT WATER RECLAMATION FACILITY
SLUDGE PRODUCTION CALCULATIONS (without thickening equipment)
Date: August 27, 2008

This sheet calculates the sludge that will be produced at the proposed MBR treatment facility

Estimated Average Daily Flows

Current =	0.045	MGD
Future =	0.200	MGD

Average Daily Flow (ADF) is used because sludge is processed on a long term basis, so daily and monthly peaks have little impact.

MBR BOD Removal

BOD- MBR Influent =	450	mg/L
BOD- MBR Effluent =	2	mg/L

Sludge Characteristics

Yn= (lb WAS/lb BOD)	0.85
Psludge	1.015
%Solids	1.5%

Formulas Used

Mass Produced = (ADF) x (8.34 [lb/MG]/[mg/L]) x (BODin - BODout) x (Yn)
Volume Produced = (Mass Produced) / ((62.4 lb/ft3) x (Psludge) x (%Solids))

Mass Produced After Nitrification/Denitrification

Current =	142.9	lb/day
Future =	635.2	lb/day

Volume of Sludge Sent to Holding Tank

Current =	150.4	lb/day	7,876	gal/week
Future =	668.6	lb/day	35,007	gal/week

%Solids Reduction in Sludge Holding Tank

20.0%	estimated from other treatment facility operational data

Total Volume of Sludge Produced

Current =	120.3	lb/day	6,301	gal/week
Future =	534.9	lb/day	28,005	gal/week

USIT WATER RECLAMATION FACILITY
SLUDGE PRODUCTION CALCULATIONS (with PAD-K thickening equipment)
Date: August 27, 2008

This sheet calculates the sludge that will be produced at the proposed MBR treatment facility

Estimated Average Daily Flows

Current =	0.045	MGD
Future =	0.200	MGD

Average Daily Flow (ADF) is used because sludge is processed on a long term basis, so daily and monthly peaks have little impact.

MBR BOD Removal

BOD- MBR Influent =	450	mg/L
BOD- MBR Effluent =	2	mg/L

Sludge Characteristics

Yn= (lb WAS/lb BOD)	0.85
Psludge	1.015
%Solids	3.0%

Formulas Used
Mass Produced = (ADF) x (8.34 [lb/MG]/[mg/L]) x (BODin - BODout) x (Yn)
Volume Produced = (Mass Produced) / ((62.4 lb/ft3) x (Psludge) x (%Solids))

Mass Produced After Nitrification/Denitrification

Current =	142.9	lb/day
Future =	635.2	lb/day

Volume of Sludge Sent to Holding Tank

Current =	75.2	lb/day	3,938	gal/week
Future =	334.3	lb/day	17,503	gal/week

%Solids Reduction in Sludge Holding Tank

40.0%	estimated from other treatment facility operational data

Total Volume of Sludge Produced

Current =	45.1	lb/day	2,363	gal/week
Future =	200.6	lb/day	10,502	gal/week

APPENDIX I

APPENDIX I
COST ESTIMATE INFORMATION

UPPER SKAGIT TRIBE
WATER RECLAMATION FACILITY
CONSTRUCTION COST ESTIMATE, AUGUST 27, 2008
MEMBRANE BIOREACTOR PROCESS (Design Average Flow = 200,000 gpd)

Item No.	Item	Description	Approx. Quantity	Unit	$/Unit	Total $
1	**MBR Water Reclamation Facility**					
a.	Excavation/Backfill	Excavation & Backfill	3,000	CY	$ 15.00	$ 45,000
b.	Equipment	Mechanical Screen (2 mm)	1	LS	$ 75,000.00	$ 75,000
		MBR Equipment Package	1	LS	$ 950,000.00	$ 950,000
		Equalization Basin (Coarse Bubble Diffusers)	1	LS	$ 15,000.00	$ 15,000
		UV Equipment (High Int., Low Pressure)	1	LS	$ 95,000.00	$ 95,000
c.	Concrete	Equalization/Grit Basin (200,000 gals)	270	CY	$ 550.00	$ 149,000
		Mechanical Screen	22	CY	$ 550.00	$ 12,000
		MBR Anoxic, PreAer, & Membrane Basins	325	CY	$ 550.00	$ 179,000
		Sludge Holding Basins (120,000 gals)	170	CY	$ 550.00	$ 94,000
		Control Building Foundation	75	CY	$ 500.00	$ 38,000
d.	Metal Buildings	Control Bldg. (30' x 80' enclosed metal bldg)	2,400	SF	$ 85.00	$ 204,000
e.	Yard Piping	Site Piping	1	LS	$ 75,000.00	$ 75,000
f.	Site Work	General Site Work	1	LS	$ 95,000.00	$ 95,000
		Sidewalks	1	LS	$ 5,000.00	$ 5,000
		Handrailing & Grating	1	LS	$ 15,000.00	$ 15,000
g.	Electrical	Lighting	1	LS	$ 15,000.00	$ 15,000
		Service Equipment	1	LS	$ 25,000.00	$ 25,000
		Feeders	1	LS	$ 29,000.00	$ 29,000
		Branch Materials & Devices	1	LS	$ 40,000.00	$ 40,000
		Instrumentation & Controls	1	LS	$ 95,000.00	$ 95,000
		Emergency Generator	1	LS	$ 80,000.00	$ 80,000
		Equipment Connections	1	LS	$ 22,000.00	$ 22,000
	Subtotal					$ 2,352,000
	Contingency (10%)					$ 235,000
	Construction Total					$ 2,587,000
	Sales Tax on Construction (0% - Tribe is exempt)					$ -
	Surveying and Engineering (15% of Construction)					$ 388,050
	Construction Phase Engineering, Observation (8% of Construction)					$ 206,960
	Total for MBR Water Reclamation Facility					**$ 3,182,000**
2	**Reclaimed Water Dis./Infiltr. Sys.**	Piping	1	LS	$ 30,000.00	$ 30,000
		Pipe Excavation/Bedding/Fill	500	CY	$ 30.00	$ 15,000
		Effluent Pumps/Well	1	LS	$ 50,000.00	$ 50,000
		Discharge Wells	2	EA	$ 18,000.00	$ 36,000
	Subtotal					$ 131,000
	Contingency (10%)					$ 13,000
	Construction Total					$ 144,000
	Sales Tax on Construction (0% - Tribe is exempt)					$ -
	Surveying and Engineering (15% of Construction)					$ 21,600
	Construction Phase Engineering, Observation (8% of Construction)					$ 11,520
	Total for Reclaimed Water Discharge/Infiltration System					$ 177,000
	Total for Items 1 and 2					**$ 3,359,000**
3	**Additional Options**					
a.		PAD-K Sludge Thickening System	1	LS	$ 315,000.00	$ 315,000
b.		Metal Building Shelter for MBR Train	3,000	SF	$ 50.00	$ 150,000
c.		Metal Building Shelter for Sludge Basins	2,000	SF	$ 50.00	$ 100,000
	Subtotal					$ 565,000
	Contingency (10%)					$ 57,000
	Construction Total					$ 622,000
	Sales Tax on Construction (0% - Tribe is exempt)					$ -
	Surveying and Engineering (15% of Construction)					$ 93,300
	Construction Phase Engineering, Observation (8% of Construction)					$ 49,760
	Total for Additional Options					$ 765,000
	Total for Items 1 through 3					**$ 4,124,000**

USIT WATER RECLAMATION FACILITY
OPERATION AND MAINTENANCE COST PROJECTION
MBR PROCESS EQUIPMENT (with PAD-K sludge thickening)
Date: August 27, 2008

O&M Items	O&M Projected Costs Low Estimate	High Estimate	Comments
Plant Influent Flow (gpd) =	200,000	200,000	Total Flow. 20-YR Projection.
Total Volume of Sludge Produced (gallons per week) =	10,500	10,500	Assume 3.0% solids and 40% sludge destruction in holding tanks
Biosolids Hauling Cost ($/gallon)	$0.05	$0.06	Vac Tank Western Services (70 mi. roundtrip), Mick V.
Farm Storage, Spreading, Permitting Cost ($/gallon)	$0.06	$0.07	Tjoelker Farms. However, may need alternate site for winter storage.
Biosolids Cost per Week ($)	$1,155	$1,365	
Biosolids Cost per Year ($/year)	**$60,060**	**$70,980**	
General Maintenance & Repair (0.5% of Construction Cost)	$12,750	$17,250	Total Construction Estimate = $3,000,000 (+/-15%)
Maintenance & Repair Cost per Year ($/year)	**$12,750**	**$17,250**	
Membrane Replacement ($/membrane)	$60	$60	Estimate from Kubota, Jim Gleason
Total No. of Membranes	2,200	2,200	
Anticipated Membrane Life (years)	15	10	Average Life = 12.5 Years
Membrane Replacement Cost ($/year, pro-rated)	**$8,800**	**$13,200**	
MBR Plant Motor HP	100	100	blowers, feed pump, mixer, permeate pumps, screen, etc.
Power Cost ($/KWhour)	$0.07	$0.09	
Operation Time (hr/week)	168	168	Operation time = 24 hrs/day, 7 days/week.
Power Cost per Week ($)	$877.30	$1,127.95	
Power Cost per Year ($/year)	**$45,619**	**$58,654**	
Contract Labor ($/hour)	$60	$60	Water & Wastewater Services, Kelly Wynn
Hours per week	20	30	
Operation Cost per Week ($/week)	$1,200	$1,800	
Operation Cost per Year ($/year)	**$62,400**	**$93,600**	
Misc Items (Lab Work, Permitting, etc.)	$10,000	$20,000	
Misc. Items Cost per Year ($/year)	**$10,000**	**$20,000**	
Annual Cost ($/year)	**$199,629**	**$273,684**	
Monthly Cost ($/month)	**$16,636**	**$22,807**	Average Monthly O&M Cost Estimate = $20,000

Alternate No. 1 - Discharge 1.0% Waste Activated Sludge back into Burlington Force Main		
Flow Cost: $1.81/ccf or $0.0024/gallon	$0.0024	per gallon *
Strength Cost for 1.0% solids: $2.14/ccf x (10,000mg/l ÷ 350 mg/L)	$0.0817	per gallon *
Projected Flow for Waste Activated Sludge	35,000	gallons per week
Total Cost to Burlington for 1.0% solids ($/week)	$2,946	
*** Biosolids Cost per Year ($/year)**	**$153,174**	

* Assume Costs to be per 2001 Negotiated Rate for (1.) Lagoon System

USIT WATER RECLAMATION FACILITY
OPERATION AND MAINTENANCE COST PROJECTION
MBR PROCESS EQUIPMENT (without sludge thickening)
Date: August 27, 2008

O&M Items	O&M Projected Costs		Comments
	Low Estimate	High Estimate	
Plant Influent Flow (gpd) =	200,000	200,000	Total Flow. 20-YR Projection.
Total Volume of Sludge Produced (gallons per week) =	28,000	28,000	Assume 1.5% solids and 20% sludge destruction in holding tank
Biosolids Hauling Cost ($/gallon)	$0.05	$0.06	Vac Tank Western Services (70 mi. roundtrip), Mick V.
Farm Storage, Spreading, Permitting Cost ($/gallon)	$0.06	$0.07	Tjoelker Farms. However, may need alternate site for winter storage.
Biosolids Cost per Week ($)	$3,080	$3,640	
Biosolids Cost per Year ($/year)	**$160,160**	**$189,280**	
General Maintenance & Repair (0.5% of Construction Cost)	$12,750	$17,250	Total Construction Estimate = $3,000,000 (+/-15%)
Maintenance & Repair Cost per Year ($/year)	**$12,750**	**$17,250**	
Membrane Replacement ($/membrane)	$60	$60	Estimate from Kubota, Jim Gleason
Total No. of Membranes	2,000	2,000	
Anticipated Membrane Life (years)	15	10	Average Life = 12.5 Years
Membrane Replacement Cost ($/year, pro-rated)	**$8,000**	**$12,000**	
MBR Plant Motor HP	85	85	blowers, feed pump, mixer, permeate pumps, screen, etc.
Power Cost ($/KWhour)	$0.07	$0.09	
Operation Time (hr/week)	168	168	Operation time = 24 hrs/day, 7 days/week.
Power Cost per Week ($)	$745.70	$958.76	
Power Cost per Year ($/year)	**$38,776**	**$49,855**	
Contract Labor ($/hour)	$60	$60	Water & Wastewater Services, Kelly Wynn
Hours per week	15	25	
Operation Cost per Week ($/week)	$900	$1,500	
Operation Cost per Year ($/year)	**$46,800**	**$78,000**	
Misc Items (Lab Work, Permitting, etc.)	$10,000	$20,000	
Misc. Items Cost per Year ($/year)	**$10,000**	**$20,000**	
Annual Cost ($/year)	**$276,486**	**$366,385**	
Monthly Cost ($/month)	**$23,041**	**$30,532**	Average Monthly O&M Cost Estimate = $27,000

Alternate No. 1 - Discharge 1.0% Waste Activated Sludge back into Burlington Force Main		
Flow Cost: $1.81/ccf or $0.0024/gallon	$0.0024	per gallon *
Strength Cost for 1.0% solids: $2.14/ccf x (10,000mg/l ÷ 350 mg/L)	$0.0817	per gallon *
Projected Flow for Waste Activated Sludge	35,000	gallons per week
Total Cost to Burlington for 1.0% solids ($/week)	$2,946	
*** Biosolids Cost per Year ($/year)**	**$153,174**	

* Assume Costs to be per 2001 Negotiated Rate for (1.) Lagoon System